Digital Techniques

EB-6201-71 LAB BOOK 595-3813-06

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Digital Techniques

EB-6201-71 LAB BOOK 595-3813-06

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Introduction

The EB-6201-71 is to be used in conjunction with the ETB-6201 or the ETB-6201-A circuit board. These products are designed to be used with the ET-3700 Trainer and the ET-3567 Trainer Backpack.

The purpose of the circuit board is to provide a visual display of the operation of real digital circuits as a variety of digital techniques are applied.

The circuit board is a demonstration board that adds another dimension to the instructional material. It can be used to perform a variety of experiments that demonstrate principles presented in the Digital Techniques course text. The circuit board can also be used for demonstrations; as a fault board for demonstrating trouble shooting techniques; and for actually troubleshoot digital circuits.

The EB-6201-71 manual is a Digital Techniques application oriented Student Laboratory Manual.

The circuit board has some unused gates to provide additional flexibility. By combining these gates with the outputs and inputs of the hard wired circuits, you can design a variety of other digital logic circuits. The only additional parts required to make the circuits operational are jumper wires.

The only difference between the ETB-6201 and ETB-6201-A circuit boards are listed below.

- All of the LEDs and two of the potentiometers on the ETB-6201-A have current limiting resistors.
- Integrated circuit chips U600 and U601 on the ETB-6201-A are different from those on the ETB-6201, although, the experiment circuits operate in the same fashion.
- The memory chip in block 8 of the ETB-6201-A is larger than the memory chip on the ETB-6201. However, the decoding principles and experiment steps are identical for both boards.
- The ETB-6201-A uses special jumper wire assemblies to interconnect pins on the circuit board, rather than the 22 gauge solid-core wires used on the ETB-6201.
- Later versions of the ETB-6201 and all of the ETB-6201-A boards use 74LS00- and 74ALS00-type integrated circuits. Earlier versions of the ETB-6201 board use standard 7400-type chips. You should refer to the original parts list supplied with the board to obtain the exact Heath part number when ordering replacement parts.

Course Purpose

Generally speaking, the purpose of this manual is to support and reinforce the material presented in the EB-6201 and EB-6201A textbooks. Specifically, they are:

1. Compare the compactness of digital integrated circuits with equivalent discrete circuits.

2. Define and demonstrate binary data and the values of Boolean variables .

3. Demonstrate the basic logic functions.

   NOT
   AND
   OR

4. Demonstrate the dual nature of logic gates and combinational logic circuits.

   NOT
   AND
   OR
   NAND
   NOR
   EOR
   ENOR
   Negated logic gates

5. Demonstrate the operation of latches and their complementary outputs.

   Bistable Multivibrator
   RS-Type
   D-Type
   JK-Type
   Switch Debouncing

6. Demonstrate binary registers.

   Shift Register
   Shift L/R
   Data Storage
   Data Routing
   Multiplication/Division

7. Demonstrate counters and decoders.

   Up/Down
   Binary
   Octal
   BCD
   Hex
   1 of 4
   1 of 10

8. Demonstrate counters using visual displays.

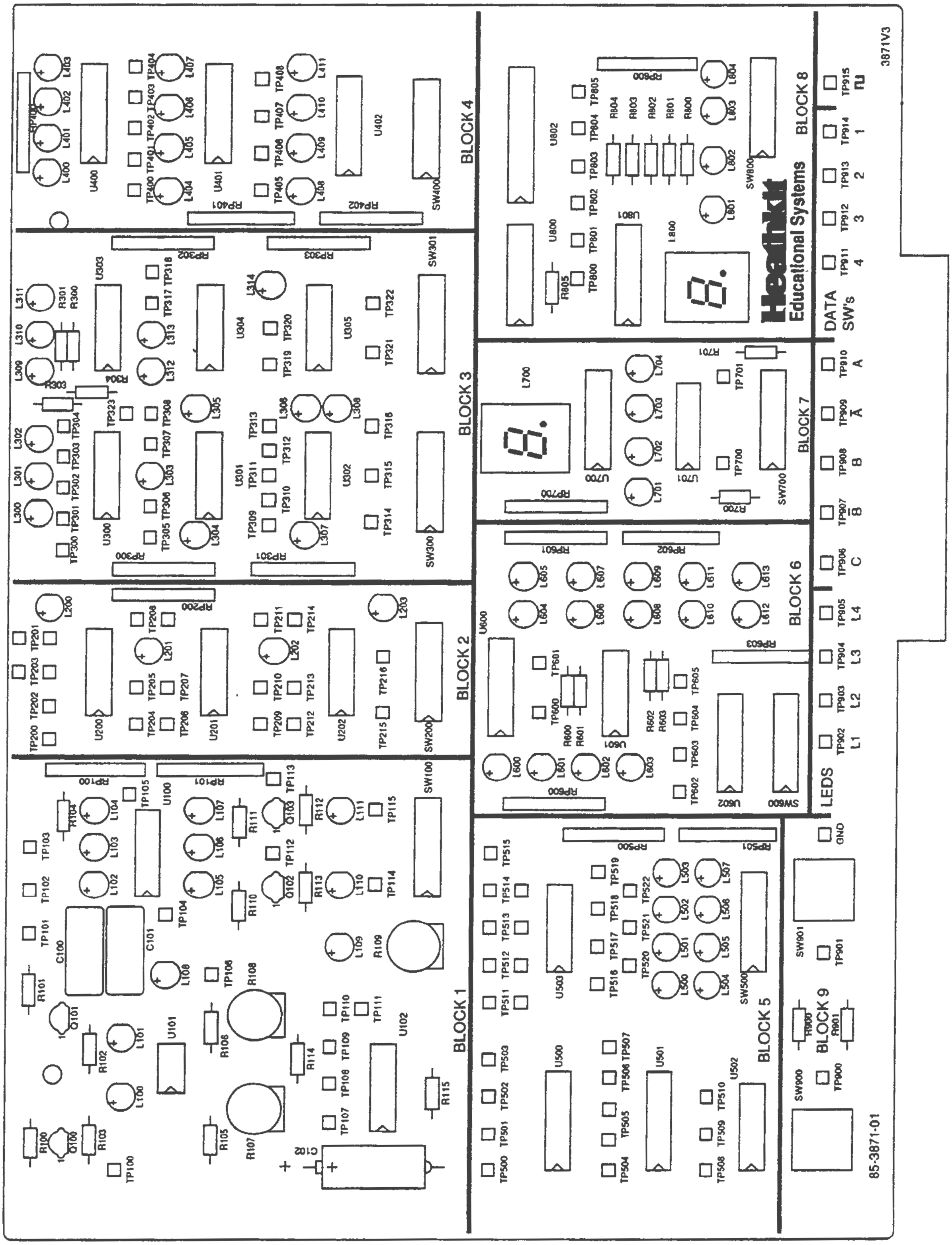
   LEDs
   7-Segment display

9. Demonstrate the use of a RAM and memory programming.

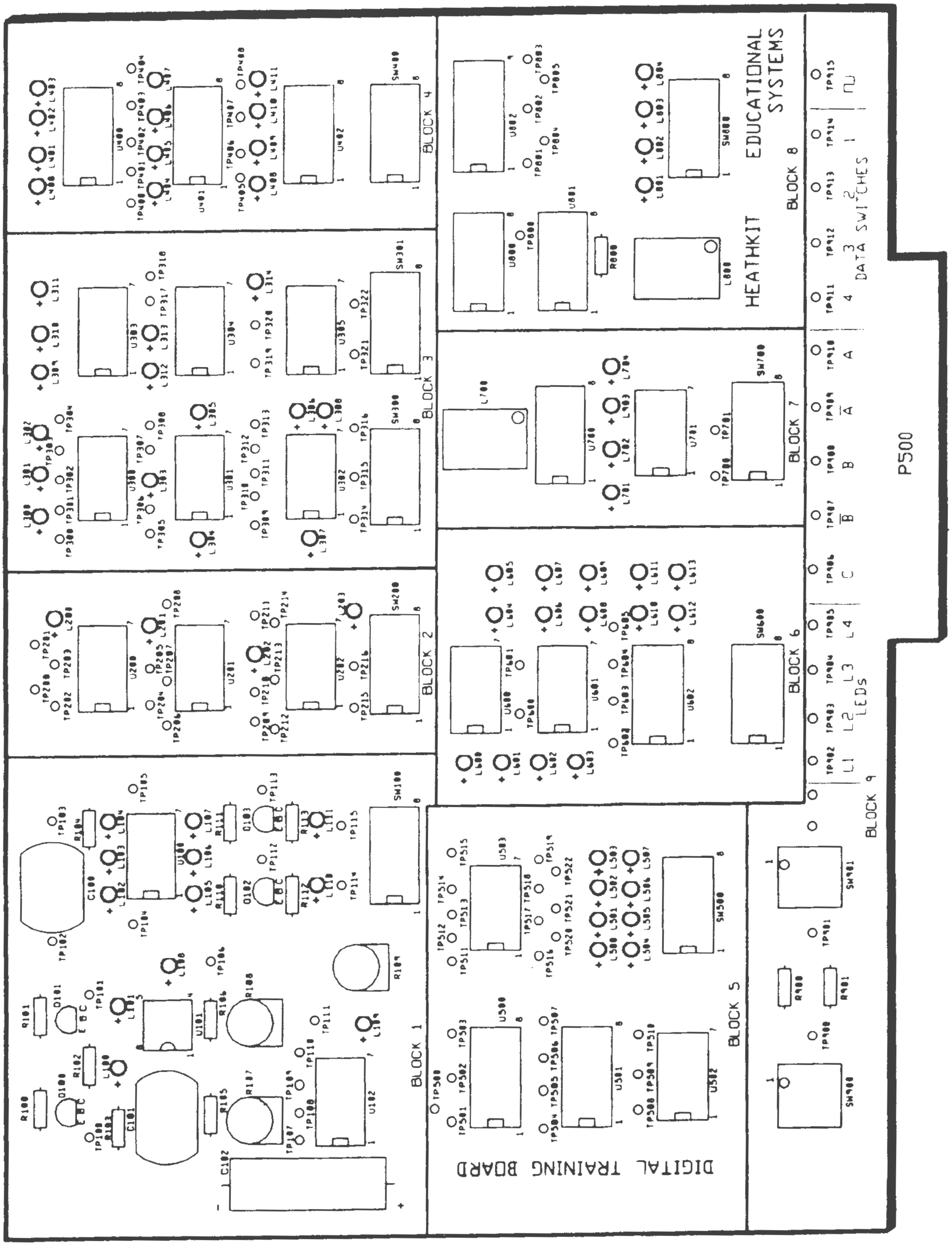
   Step counter
   Memory Storage

10. Demonstrate digital trouble shooting techniques using:

ETB-6201-A Circuit Board



ETB-6201 Circuit Board



Parts List

List of parts on the ETB-6201 and ETB-6201-A circuit boards

PART NO.	QTY.	DESCRIPTION
Block 1		
6-101-12	2	100 ohm, 1/4-watt resistors
6-102-12	5	1000 ohm, 1/4-watt resistors
6-103-12	3	10 kilohm, 1/4-watt resistors
6-104-12	1	100 kilohm, 1/4-watt resistor
6-221-12	1	220 ohm, 1/4-watt resistor
6-332-12	1	3300 ohm, 1/4-watt resistor
9-231	2	220 ohm SIP resistors
10-1138	1	10 kilohm control
10-1145	2	2 megohm controls
25-935	1	1000 microfarad electrolytic capacitor
27-86	2	0.47 microfarad Mylar capacitors
60-653	1	8-section dip switch
412-641	2	Amber LEDs
412-642	5	Green LEDs
412-654	5	Red LEDs
417-801	4	MPSA-20 NPN Transistors
432-1689	16	Wire connectors (ETB-6201)
432-2020	16	Connector pins (ETB-6201-A)
434-230	1	8-pin socket
434-298	2	14-pin sockets
442-53	1	555 Timer
443-755	2	74LS04 Hex inverters

PART NO.	QTY.	DESCRIPTION
Block 2		
9-231	1	220 ohm SIP resistor
60-653	1	8-section dip switch
412-641	1	Amber LED
412-642	1	Green LED
412-654	1	Red LED
412-645	1	Clear LED
432-1689	17	Wire connectors (ETB-6201)
432-2020	20	Connector pins (ETB-6201-A)
434-298	3	14-pin sockets
443-755	1	74LS04 Hex inverter
443-780	1	74LS08 Quad-AND
443-875	1	74LS32 Quad-OR
Block 3		
6-103-12	2	10 kilohm, 1/4-watt resistors
6-104-12	2	100 kilohm, 1/4-watt resistors
9-231	4	220 ohm SIP resistors
60-653	2	8-section dip switches
412-641	3	Amber LEDs
412-642	5	Green LEDs
412-654	6	Red LEDs
412-645	1	Clear LED
432-1689	23	Wire connectors (ETB-6201)
432-2020	23	Connector pins (ETB-6201-A)
434-298	6	14-pin sockets
443-695	1	4001 Quad-NOR
443-755	1	74LS04 Hex inverter
443-779	1	74LS02 Quad-NOR
443-891	1	74LS86 Quad-EOR
443-1080	2	74ALS00 Quad-NANDs
Block 4		
9-231	3	220 ohm SIP resistors
60-653	1	8-section dip switch
412-642	4	Green LEDs
412-654	8	Red LEDs
432-1689	9	Wire connectors (ETB-6201)
432-2020	9	Connector pins (ETB-6201-A)
434-299	3	16-pin sockets
443-781	1	74LS75 D-type flip-flop
443-829	2	74LS76 JK flip-flops

PART NO.	QTY.	DESCRIPTION
Block 5		
9-231	2	220 ohm SIP resistors
60-653	1	8-section dip switch
432-1689	23	Wire connectors (ETB-6201)
432-2020	28	Connector pins (ETB-6201-A)
434-298	2	14-pin sockets
434-299	2	16-pin sockets
412-642	4	Green LEDs
412-654	4	Red LEDs
443-814	1	74LS95 Shift register
443-829	2	74LS76 JK flip-flops
443-1080	1	74ALS00 Quad-NAND
Block 6		
6-471-12	4	470 ohm, 1/4-watt resistors
9-231	4	220 ohm SIP resistors
60-653	1	8-section dip switch
412-642	10	Green LEDs
412-654	4	Red LEDs
432-1689	6	Wire connectors (ETB-6201)
432-2020	6	Connector pins (ETB-6201-A)
434-298	1 or 2	14-pin sockets
434-299	1 or 2	16-pin sockets
443-755	1	74LS04 Hex inverter (ETB-6201)
443-807	1 or 2	74LS42 Decoder
443-891	1	74LS86 Quad-EOR (ETB-6201-A)
443-1080	1	74ALS00 Quad-NAND (ETB-6201)
Block 7		
6-103-12	2	10 kilohm, 1/4-watt resistors
9-231	1	220 ohm SIP resistors
60-653	1	8-section dip switch
411-885	1	7-segment LED display
412-654	4	Red LEDs
432-1689	2	Wire connectors (ETB-6201)
432-2020	2	Connector pins (ETB-6201-A)
434-298	1	14-pin socket
434-299	1	16-pin socket
443-694	1	9368 Driver
443-813	1	74LS90 BCD counter

PART NO.	QTY.	DESCRIPTION
Block 8		
6-102-12	1	1000 ohm, 1/4-watt resistor
6-103-12	1	10 kilohm, 1/4-watt resistor
6-153-12	4	15 kilohm, 1/4-watt resistors
9-231	1	220 ohm SIP resistor
60-653	1	8-section dip switch
411-885	1	7-segment LED display
412-642	4	Green LEDs
432-1689	6	Wire connectors (ETB-6201)
432-2020	6	Connector pins (ETB-6201-A)
434-299	2	16-pin sockets
434-310	1	18-pin socket (ETB-6201)
443-694	1	Driver (9368)
443-764	1	2114 RAM (ETB-6201)
443-815	1	74LS193 Binary counter
443-1559	1	5188/6288/P4C188 RAM (ETB-6201-A)
Block 9 (bottom row)		
6-101-12	2	100 ohm, 1/4-watt resistors
64-910	2	Push button switches
432-1689	16	Wire connectors (ETB-6201)
432-2020	17	Connector pins (ETB-6201-A)
462-1145	1	White switch cap
462-1147	1	Blue switch cap
Miscellaneous		
134-3974	12	Jumper wire assemblies

Experiments

Introduction

To do the experiments in this manual requires a minimum of wiring time. The majority of the lab time can be used to observe and analyze circuit operation.

The only external parts required to activate the circuits are jumper wires (22 gauge, single-conductor, insulated copper wire) for the ETB-6201 circuit board or jumper wire assemblies for the ETB-6201-A circuit board. Because this text is written to accommodate both circuit boards, we will simply tell you to interconnect test points with jumper wire, and not get specific as to the type of jumper wire.

Several experiments require multiple wire connections to a single test point. Use the trainer breadboard for those connections on the ETB-6201. Multiple connector pins are provided for those connections on the ETB-6201-A.

Visual display devices are used in each circuit so that you can easily identify the circuit's specific operation or application.

The circuits are wired so that the dip switches can be used to turn off all of the displays except the circuit that you are analyzing. Before you begin an experiment, always make sure all of the 8-segment dip switches in all of the circuit blocks are set to their down (off) positions. While the circuits cannot be damaged by leaving the switches up (on), the results of an experiment could be confusing if you have more switches on than what is required to perform a particular operation.

The first 32 experiments deal with circuit identification and **DO NOT** require test equipment.

The last eight experiments deal with troubleshooting and **DO** require test equipment.

Experiment 1
Discrete Inverters

Purpose

To demonstrate the inverter function.

To show the actual circuitry of a discrete dual inverter.

To explain the values of binary bits.

To explain the primary use of double inversion in digital circuits.

Introduction

This experiment is a review of the common-emitter amplifier that you studied, and used, in both the Semiconductor Devices and Electronic Circuit courses. You should have remembered that it requires a 3-element discrete device to cause polarity inversion.

In digital circuits, the term for an inversion is the NOT function. Since digital circuits use binary data, there are only two values that the data (a bit) can be. It can either be 1 or 0. Whatever its value, when passed through a NOT gate it is converted (inverted/complemented) to its other value.

Procedure

1. Connect a jumper wire between TP100 and TP106 in block 1.

   Set the 8-position dip switch (SW100) to 1, 3, and 7 up (ON).

   Turn the trainer on and observe the LEDs in block 1.

   Center R107 and R108.

2. Which of the blinking LEDs are in phase?

   ______________ ______________ .

3. What is the phase relationship of L100 compared to L108?

   ________________________ .

4. When L100 is lit, is the Collector of Q100 high or low?

   ________________________ .

5. How many passive and active components are in the discrete dual inverter, not including the LEDs?

   passive _______ active ________ .

6. R107 and R108 can be used to stop the clock with either L100 or L101 lit. When L100 is lit and the output is taken at TP101, is the circuit's output high or low? Refer to Figure 1-1.

   ________________________ .

7. What is the primary use of a double inverter in a digital circuit?

   ____ .

Set all dip switches low, turn the trainer off, and read the summary. Follow this procedure for each of the following experiments.

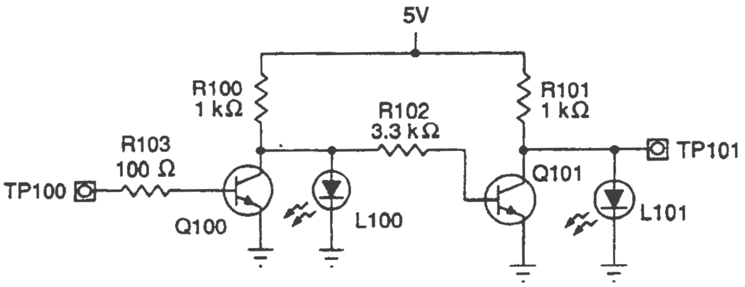


Figure 1-1

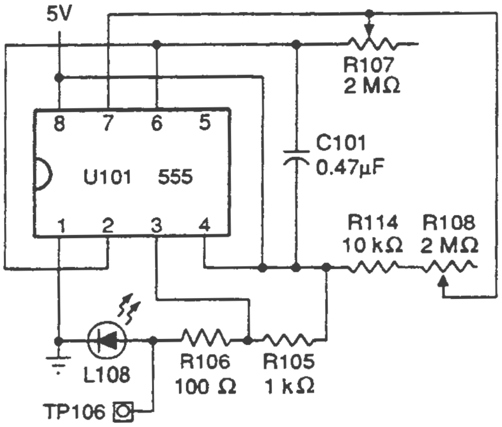


Figure 1-2

Summary

The purpose of using an even number of inverters in series is to program a delay between gates. In high speed circuits, this helps to eliminate **race problems.**

A race problem occurs when a signal reaches a gate before the gate completes its prior function. When this happens the gate can't react to the change at its input and an input pulse may be lost.

Each component (gate) has a transient response time, which is defined as its **propogation delay.**

An odd number of inverters provides polarity inversion as well as programmed delays.

A slow clock pulse is used as an input signal to allow the LEDs and your eyes to follow the changes caused by the pulse train. To see a propogation delay the signal frequency must be increased to a very high frequency and routed through many inverters. Then, with a dual trace oscilloscope, you can compare the final output pulse to the original input pulse to actually see the programmed delay. The oscilloscope can also be used to see when the pulse is high or low, at any point, in the circuit.

In this dual inverter, you applied the input signal to the base of Q100 and observed that the amber (L108) and red (L101) LEDs both light at the same time. The red LED is connected to the collector of Q101 which is double inversion when compared to the amber LED(L108).

The green LED(L100) lights when the collector of Q100 goes high.

The overall circuit output (TP101) is high, when Q100 is conducting, and the red LED is lit. At this time, the green LED (L100) is out. This assumes that when the amber LED (L108) is lit, the clock output is a binary one.

The red (L101) and amber (L108) LEDs are in phase and the green LED (L100) is 180 degrees out of phase (polarity inversion) with the input signal.

Experiment 2
Digital Hex Inverter

Purpose

To show the actual circuitry of a hex inverter.

To compare the compactness of a digital circuit to a compatible discrete circuit.

Introduction

This experiment shows that the 7404 hex inverter contains 6 inverters in a single chip. The simplicity of the circuit wiring and the circuit density are its primary advantages over the discrete dual inverter used in Experiment 1. It provides three times as many functions as the discrete dual inverter with fewer components (excluding the LED indicators) and takes up less circuit board space.

In this experiment, you will route the input signal from the discrete dual inverter to the Hex inverter.

Procedure

1. Connect a jumper wire between TP101 and TP104.

   Connect a jumper wire between TP106 and TP100.

   Set the 8-position dip switch (SW100) to 1, 2, 3, and 7 up.

   Turn the trainer on and observe the LEDs in block 1.

2. What do you notice about the blinking red LEDs?

   ____.

   What do you notice about the blinking green LEDs?

   ____.

3. Assume that the lit amber LED (L108) indicates a binary 1 input. When the red LEDs in the hex inverter are lit are the outputs of inverters 1, 3, and 5 high or low?

   ____________________.

4. How many passive and active components are used with the hex inverter, not including the LEDs or current-limiting resistors?

   Passive ________ Active ________

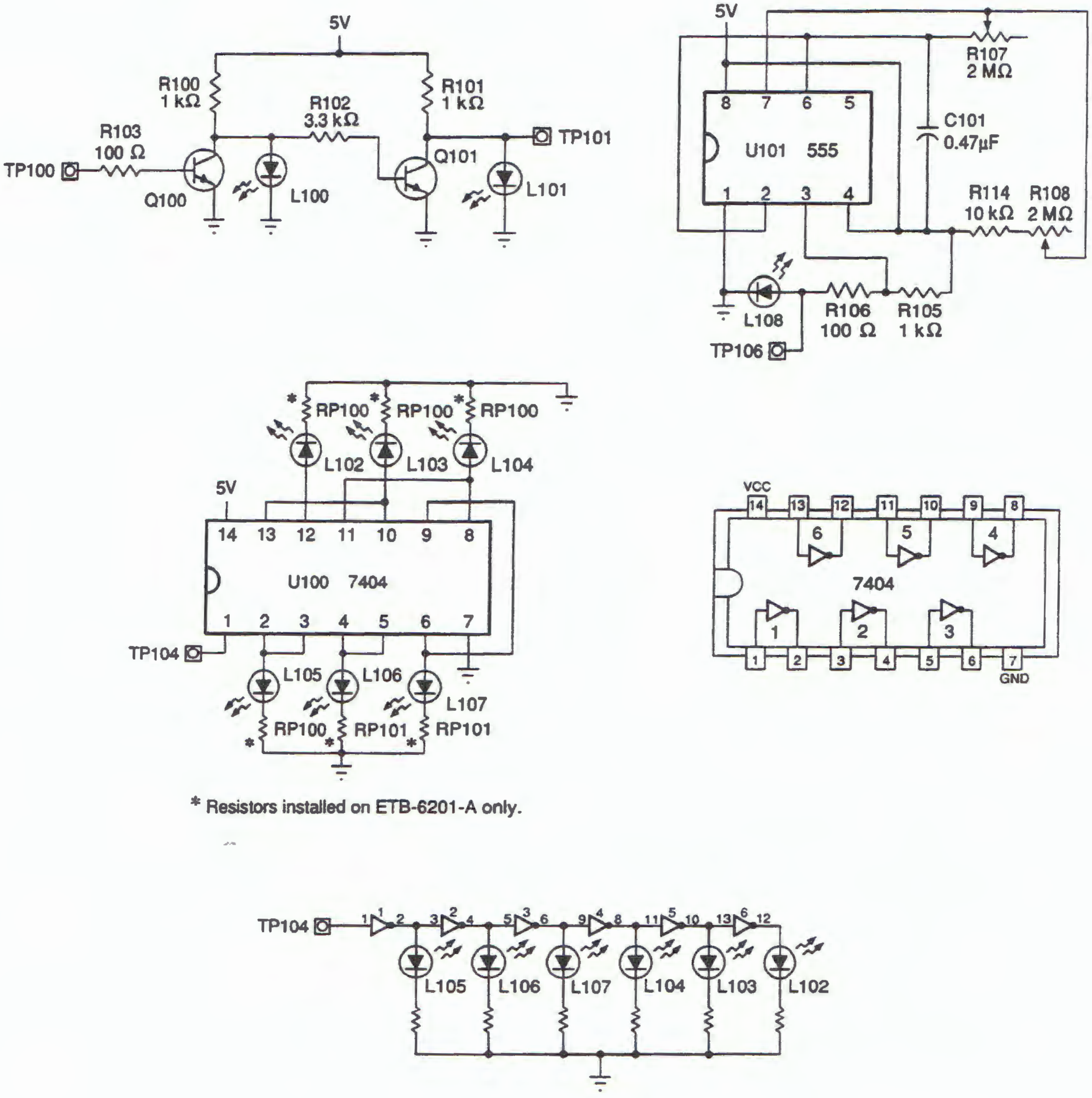
5. Write a comparison between the hex inverter and the discrete dual inverter shown in Experiment 1.

   ____

   ____

   ____.

Set the dip switches low, turn the trainer off, and read the summary.



* Resistors installed on ETB-6201-A only.

Figure 2-1

Summary

In the hex inverter, you applied the input signal to pin 1 (TP-104) of the 7404 integrated circuit. The terms integrated circuit, IC, and chip are used interchangeably in most digital courses and equipment.

The LEDs (L102 through L107) are connected to the outputs of the 6 inverters. The green LEDs are tied to the outputs of inverters 1, 3, and 5. Lit green LEDs indicate that the output of these inverters are high (1s). This indicates that the clock is low at this time. Note that the output of the inverter is tied to the input of the following inverter.

When the red LEDs are lit the green LEDs are out. Since the red LEDs are in phase with L108 they indicate that the clock is high when they are lit.

In other words, the red and green LEDs in this experiment are compliments of each other.

The signals to the red and green LEDs are 180 degrees out of phase (inverted) with each other.

You should have noticed that the IC hex inverter takes up approximately the same space on the circuit board as the dual discrete inverter. However, it requires fewer parts and provides 3 times as many outputs. The IC chip also consumes less power than the discrete dual inverter.

When a single function is to be accomplished, there is very little advantage in selecting an integrated circuit over a discrete circuit. However, when the number of functions are increased, the integrated circuit provides a definite advantage.

At extremely high frequencies, discrete circuits are considered capable of operating at higher speeds than their IC counterparts. This is true because most ICs have a higher input capacitance than compatible discrete circuits.

As you know from your earlier studies; RC time is directly proportional to response time; and time to respond is inversely proportional to frequency response. Hence, the longer the RC time the lower the frequency of operation.

$$T = \frac{1}{F}.$$

Experiment 3
The Basic Discrete Flip-Flop

Purpose

To show the actual circuitry of a Flip-Flop.

To demostrate complementary outputs.

To explain a binary data storage device.

To demonstrate the flexibility of a Flip-Flop.

Introduction

This experiment is a review of the bistable multivibrator, or flip-flop, that you studied in Electronic Circuits.

The flip-flop is the basic building block of a digital computer. In digital computers, it is used to invert a pulse train, store a binary bit, compensate for line losses; and to reshape a pulse that has been distorted.

Distortion and line losses will be demonstrated later using an oscilloscope.

Procedure

1. Connect a jumper wire between TP114 and data switch 1, (TP914).

   Make sure data switch 1 (SW1) is in the down position (off).

   Set the 8-position dip switch (SW100) to 4 and 8 up. All other switches should be down at this time.

   Turn the trainer on and observe the LEDs in block 1.

2. Which LED is lit?

   ________________________ .

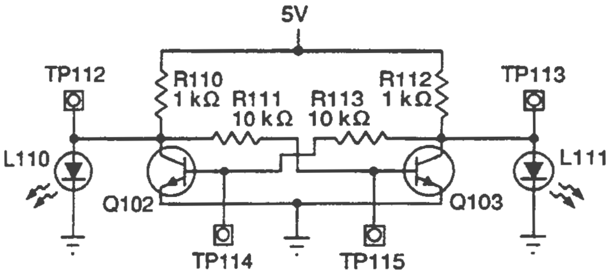


Figure 3-1

3. What is the phase relationship of L110 compared to L111?

   ________________________ .

4. When the red LED is lit is output 1 (TP112) high or low?

   ________________________ .

5. While observing L110 and Ll11 turn data switch 1 on. Did the LEDs switch states? Turn data switch 1 off.

   ________________________ .

6. Move the jumper wire from TP114 to TP115. Did the LEDs change states?

________________________.

7. Switch data switch 1 on and off four times. How many times did the LEDs change states?

________________________.

8. With data switch 1 off, move the jumper from TP115 to TP114 and back to TP115. Did the LED states follow the jumper wire?

________________________.

How many change of states occured?

________________________.

Why did this happen?

____

____

9. Turn data switch 1 on and again move the jumper from TP115 to TP114 and back to TP115. Did the LEDs change states when the jumper wire was moved?

________________________.

Explain the difference in the LEDs responses when data switch 1 is high and when it is low.

____.

Why did this happen?

____.

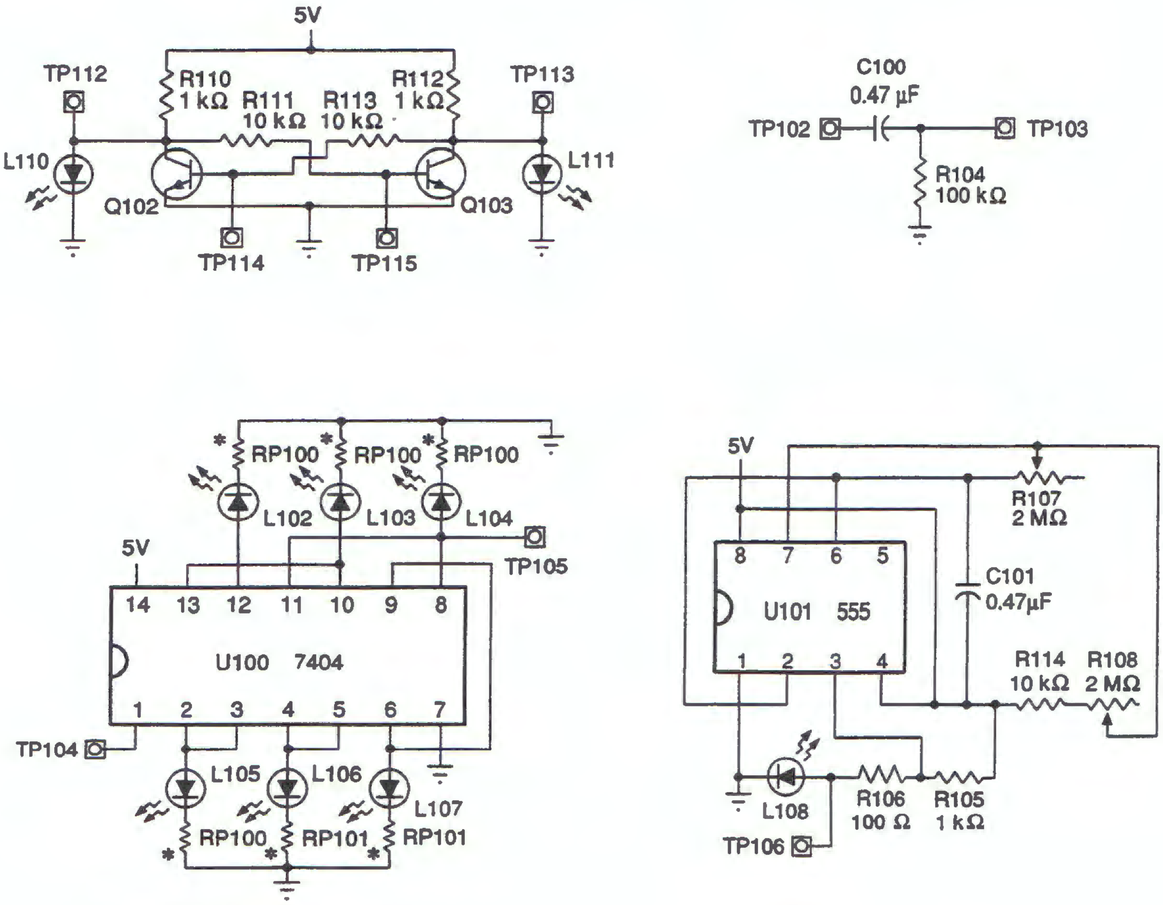
10. Turn the trainer off and install jumper wires in the circuit as listed below.

    Connect a jumper wire between TP106 and TP104.

    Connect a jumper wire between TP105 and TP102.

    Connect a jumper wire between TP103 and TP115.

    Set SW100 to 2, 3, 4, 7, and 8 up.



* Resistors installed on ETB-6201-A only.

Figure 3-2

11. Turn the trainer on and observe the LEDs in block 1. Which LEDs are in phase with L111?

    ____.

12. Move the jumper from TP115 to TP114. Which LEDs are now in phase with L111?

    ____.

13. The red LED in the discrete multivibrator (flip-flop) is lit and the output is taken from TP113.

    Is the output (TP113) high or low at this time?

    ____________________.

14. Which LED must be lit for the flip-flop to be considered set?

    ____________________.

Summary

The bistable multivibrator is the basic flip-flop used in digital computers. It has the capability of providing complementary outputs. When output 1 is high, output 2 must be low. Either output may be labeled as the set (1) or reset (0) state of the flip-flop.

Once a bistable flip-flop is set, it can't be flipped (switched) between states by reapplying the same polarity pulse to the same input. Likewise, the flip-flop can't be reset by reapplying the same polarity pulse to the same input.

To cause a continuous change of state the same polarity pulse can be alternately applied to inputs 1 (TP114) and 2 (TP115). Another technique is to apply alternate polarity pulses to the same input. This is accomplished by a clock pulse train or by switching data switch 1 between high and low.

It is also possible to apply the same polarity pulse to both inputs at the same time. This can cause the flip-flop to change states each time a pulse is applied, but usually requires the use of steering diodes to direct the proper polarity pulse to the correct transistor.

Therefore, the bistable multivibrator can be used as a 1:1 coupler (buffer); 2:1 frequency divider; to invert a pulse train; to restore a waveshape; to convert input signals to rectangular outputs; and to store a binary bit.

To invert a pulse train, you simply route the pulse train (TP103) to either TP114 or TP115. When connected to TP114, the red LEDs are all in phase with each other. When connected to TP115, L111 is in phase with the green LEDs in the hex inverter.

Experiment 4
Analog Clock

Purpose

To demonstrate the function of a clock circuit.

To show the circuitry of a 555 timer used as a clock.

To demonstrate the generation and control of a pulse train.

Introduction

This experiment is a review of the 555 timer that you studied in Electronic Circuits and used in Experiments 1, 2, and 3.

The timer can be used as a driven or free running multivibrator. The free running multivibrator is often referred to as an astable multivibrator, rectangular wave generator, or a clock circuit.

The 555 timer is classified as an analog component. Therefore, all IC chips are not exclusively digital devices.

Procedure

1. Set SW100 to 3 and 7 up. Turn the trainer on and observe L108.

   Center potentiometers R107 and R108.

2. Using the sweep second hand of a watch or clock, time the blink rate of the LED and record the time of one cycle.

   ______________________________.

   Calculate the clock frequency.

   ______________________________.

3. Readjust R107 until the LED never goes out, but changes in brilliance can still be detected. Estimate the clock's upper frequency limit.

   ______________________________.

4. Readjust R107 and R108 to slow the clock frequency to its slowest operating speed.

   Estimate the frequency range of the analog clock circuit.

   ______________________________.

5. Turn the trainer off and connect jumper wires as listed below.

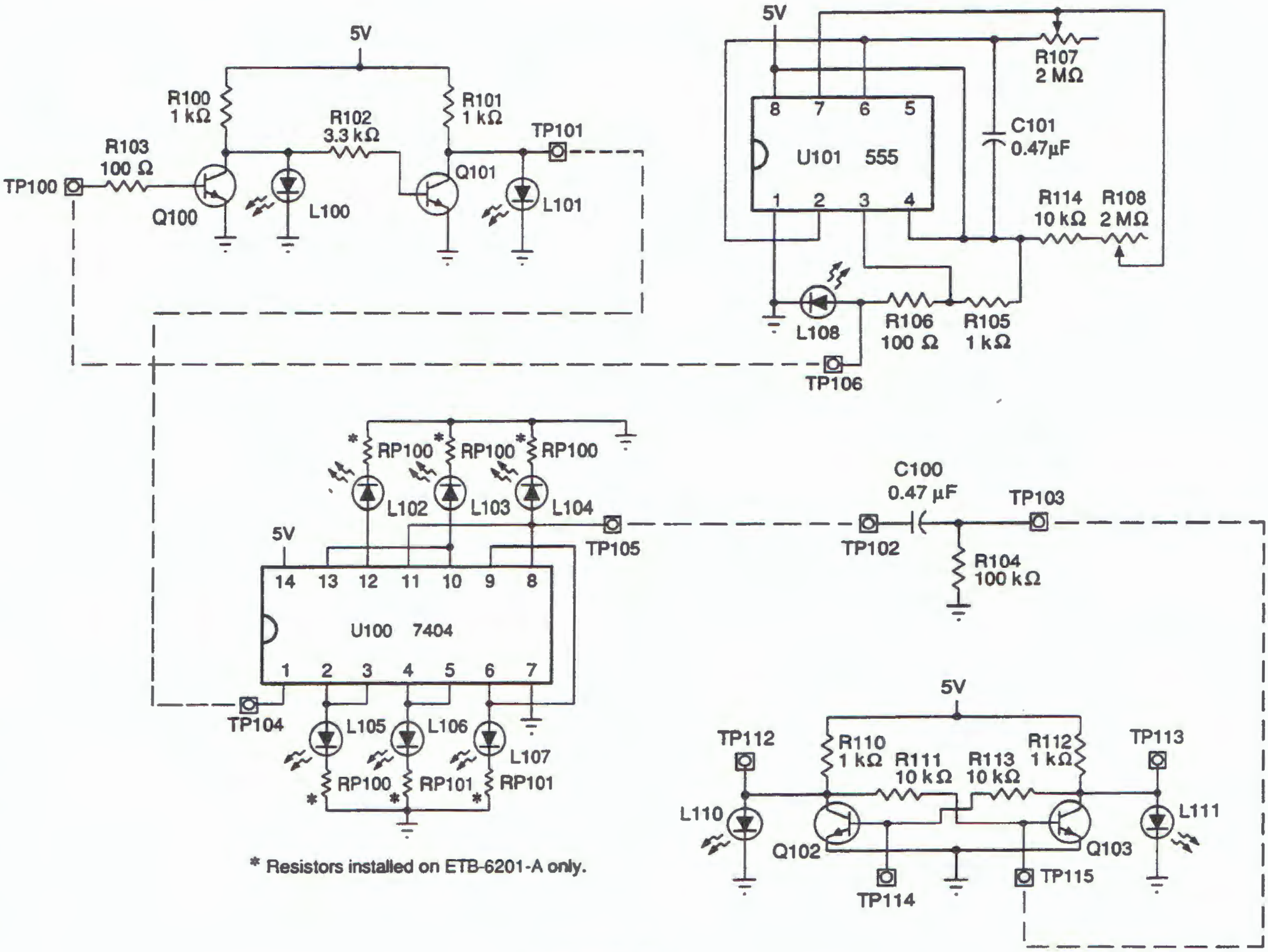
   Connect a jumper wire between TP106 and TP100.

   Connect a jumper wire between TP101 and TP104.

   Connect a jumper wire between TP105 and TP102.

   Connect a jumper wire between TP103 and TP115.

   Set SW100 to 1, 2, 3, 4, 7, and 8 up.



* Resistors installed on ETB-6201-A only.

Figure 4-1

6. Turn the trainer on and observe the LEDs in block 1.

   What do you notice about the phase relationship of the LEDs with reference to LED L108?

   green LEDs ______________________

   red LEDs ______________________

7. Are all of the red LEDs in block 1 in phase with each other?

_________________________ .

8. How could you most easily change the circuit so that all of the reds are in phase?

____ .

9. Adjust the potentiometers until you can barely distinguish the fastest blinking rate of the green LEDs.

Is the blink rate of the amber and red LEDs the same as the green LEDs?

_________________________ .

10. List the LED response time from fastest to slowest by the 3 colors of LEDs in block 1. R107 may have to be readjusted to distinguish between the LEDs response times.

_____________ _____________ _____________ .

11. Center R108 and adjust R107 fully CCW until L108 stays lit. At this time are the red or green LEDs lit?

_________________________ .

Explain why this condition occurs.

____ .

12. How is it possible to have either the red (L111) or green (L110) LEDs lit with the clock locked up?

____.

13. What are the primary frequency-determining components in the clock circuit?

__________________________.

Summary

The 555 timer chip is classified as an analog device. However, when saturated, it provides a string of rectangular pulses that are digital in nature. In other words, the output varies between a maximum high and low almost instantly. The maximum highs are defined as ones and the maximum lows are defined as zeros, when **positive logic** is used.

When using **negative logic**, the maximum highs are defined as zeros and the maximum lows are defined as ones.

When LEDs are used, they can represent both a one or zero by simply turning the LED on or off. In many cases, two different color LEDs are used and each color is defined as either a one or zero.

R107, R108, and C101 are the primary frequency determining components.

All of the red LEDs, except L111 are in phase. L111 can be switched in phase by moving the jumper wire from TP115 to TP114.

When R107 is adjusted to keep L108 lit, the clock is locked high and the red LEDs should be lit.

When R108 is adjusted to keep L108 out, the clock-is locked low and the green LEDs should be lit.

This assumes that the red LEDs indicate ones and the green LEDs represent zeros.

Experiment 5
The Versatile 7404

Purpose

To demonstrate another application for the hex inverter.

To show the actual circuitry of a simple digital clock.

To provide another example of circuit density between similar analog and digital circuits.

Introduction

This experiment is another application of the 7404 hex inverter.

In digital circuits, the term for an inversion is the NOT function. Since with digital circuits you are using binary data, there are only two values that the binary data (a bit) can be. It can either be 1 or 0. Whatever its value, when passed through a NOT gate it is converted (inverted/complemented) to its other value.

In this experiment, you are only using part of the chip for the clock function. The unused gates are available to perform other inverter functions.

Procedure

1. Set SW100 to 2 and 5 up. Adjust R109 to the 10 o'clock position. Turn the trainer on and observe the action of L109. (If L109 is not blinking, turn R109 counterclockwise until L109 starts to blink.)

   What is the approximate frequency of the clock circuit?

   ______________________.

2. Turn the trainer off and connect a jumper wire between TP111 and TP104 in block 1.

   Turn the trainer on and observe the LEDs.

   Is the clock operating?

   ______________________.

   If not, readjust R109 to restart the clock.

3. What is the approximate duty cycle of the clock?

   ______________________.

   What is duty cycle?

   ____.

4. Turn R109 slightly counterclockwise and observe the operation of the blinking LEDs.

   Did the frequency of the clock increase or decrease?

   ______________________.

   Did the clock's duty cycle increase/decrease/stay the same?

   ______________________.

5. Carefully adjust R109 and note the effect on the blinking LEDs.

   Does clockwise (CW) rotation result in an increased or decreased frequency of operation?

   ______________________.

6. By adjusting R109 can you cause the digital clock to operate at 1 Hz?

   ______________________.

7. What are the approximate ranges that the digital clock can operate between?

   ______________ and ______________.

8. What is the significant difference in circuit components between the analog and digital clocks?

   ____ .

9. What special precaution must be taken when using an electrolytic capacitor such as the one used in the digital clock circuit?

   ____ .

10. Which are the frequency determining components in the digital clock circuit?

    ____ .

11. How many of the gates in the hex inverter are required to perform the clock function?

    ______________________.

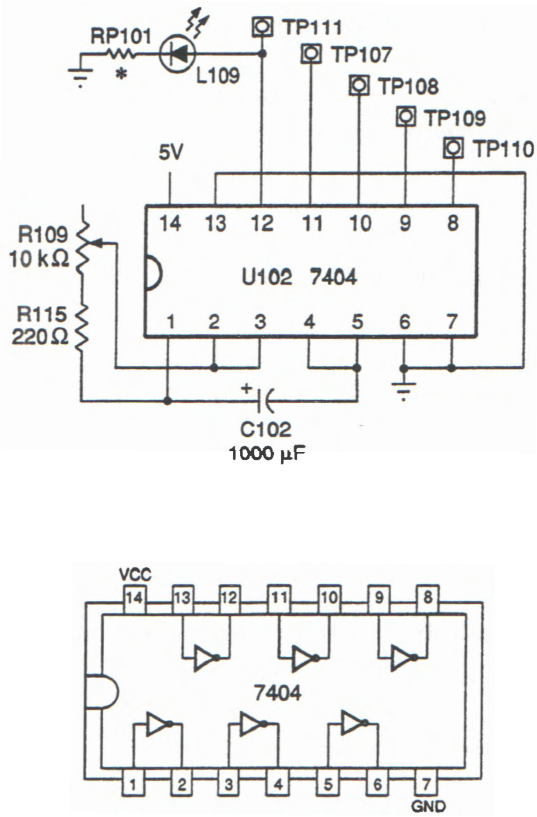

RP101
*
L109
TP111
TP107
TP108
TP109
TP110
5V
R109
10 kΩ
R115
220 Ω
14 13 12 11 10 9 8
U102 7404
1 2 3 4 5 6 7
+
C102
1000 µF
VCC
14 13 12 11 10 9 8
7404
1 2 3 4 5 6 7
GND

Figure 5-1

Summary

The circuit in Figure 5-1 is functioning as a clock circuit with a frequency range of approximately 0.1 Hz to 2 Hz with a duty cycle that varies from approximately 30% to over 95%.

It is capable of driving the same circuits that the analog clock did in Experiment 4.

When using **electrolytic capacitors, proper polarity** must be observed.

Since a green LED is connected to the output of the first inverter, when it is lit there is a low applied to the input of the first inverter. Therefore, when the clock goes low, the green LEDs are lit.

When the red LEDs are lit, the pulse from the clock circuit must be high.

R109 and C102 are the primary frequency determining components in the digital clock circuit.

The digital clock is not as easily controlled at these low frequencies as the analog clock circuit used earlier.

The digital clock circuit uses 2/3 of the 7404 chip.

Experiment 6
The 7408 Chip

Purpose

To demonstrate a Logic function.

To explain the values of Boolean variables.

To provide practice in evaluating truth tables.

To identify a particular chip by its logic operation.

Introduction

In this experiment, you will program the binary inputs of zero and one as Boolean variables A and B. Next, you will evaluate the circuit's operation by plotting the actions of an LED in a truth table.

In digital circuits, the term for an inversion is the NOT function. When using Boolean variables, they can be represented as either a one or zero by applying the NOT sign over the variable to indicate a zero. For example, when $A = 1, \overline{A} = 0$.

Remember that a binary bit can be either a one or a zero. Whatever its value, when passed through a NOT gate it is converted (inverted/complemented) to its other value.

Procedure

1. Connect a jumper wire between TP209 and data switch 1 (TP914).

   Connect a jumper wire between TP210 and data switch 2 (TP913).

   Set the data switches on the trainer to off.

2. Set the 8-position dip switch (SW200) to 1, 3, and 8 up.

   Turn the trainer on and observe the LEDs near the 7408 chip in block 2.

   Cycle the data switches through the positions shown in the truth table. Data SW1 is A and data SW2 is B.

3. Plot the truth table outputs assuming that a lit LED indicates a binary 1.

4. Which LED lit?

   ______________.

A	B	X
0	0	
0	1	
1	0	
1	1	

Figure 6-1

5. Write the Boolean equation that describes the operation of the LED listed in step 4.

   ______________.

6. What basic logic function does your Boolean equation describe?

   ______________.

Summary

The logic function performed in this experiment is the AND function as indicated by the amber LED, L202.

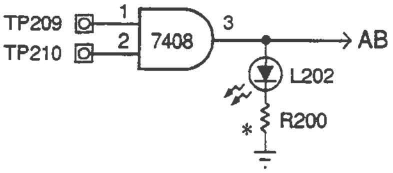
The LED lights only when both Boolean variables are equal to binary 1.

All of the inputs to an AND gate must equal 1 for its output to equal 1.

The 7408 chip is a Quad-AND. In other words, this chip contains four 2-input AND gates (logic functions).

In analog terms, this would be called a coincidence amplifier. A coincidence amplifier provides an output only when all of its inputs have an applied signal.

The NOT function is one of the basic logic gates. The AND function is another of the basic logic gates.



* Resistors installed on ETB-6201-A only.

Figure 6-2

Experiment 7
The 7432 Chip

Purpose

To demonstrate a Logic function.

To provide practice in using Boolean variables.

To provide practice in evaluating a truth table.

To identify a particular chip by its logic operation.

Introduction

In this experiment, you will program the binary inputs of zero and one as Boolean variables A and B and evaluate the circuit's operation by plotting the actions of an LED in a truth table.

In digital circuits, the term for an inversion is the NOT function. When using a Boolean variable, it can be represented as either a one or zero by applying the NOT sign over the variable to indicate a zero ($A = 1$, $\overline{A} = 0$).

Remember that a binary bit can be either one or zero. Whatever its value, when passed through a NOT gate it is converted (inverted/complemented) to its other value.

Procedure

1. Connect a jumper wire between TP211 and data switch 1 (TP914).

   Connect a jumper wire between TP215 and data switch 2 (TP913).

   Set the data switches on the trainer to off.

2. Set SW200 to 1, 4, and 7 up. Turn the trainer on and observe the LEDs in block 2.

   Cycle the data switches through the positions shown in the truth table. Data SW1 is A and data SW2 is B.

A	B	X
0	0	
0	1	
1	0	
1	1	

Figure 7-1

3. Plot the truth table outputs assuming that a lit LED indicates a binary 1.

4. Which LED lights?

   ________________.

5. Write the Boolean equation that describes the operation of the LED listed in step 4.

   ________________.

6. What basic logic function does your Boolean equation describe?

   ________________.

Summary

The logic function performed in this experiment is the OR function as indicated by the green LED (L201).

The LED lit when either or both Boolean variables equal binary 1.

An OR gate requires that only one 1 be applied to its inputs to obtain a 1 at its output.

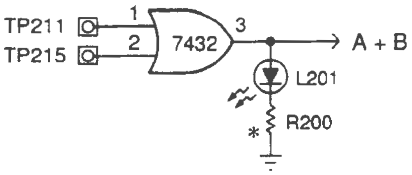
This OR gate has an output for three of the four possible input combinations.

A logic circuit with 2 Boolean variables has 4 possible input combinations (00, 01, 10, and 11) and all except 00 provide a 1 in the output as shown by the green LED being lit.

The 7432 chip is a Quad-OR. In other words, this chip contains four 2-input OR gates (logic functions).

In analog terms, this is the same as a standard amplifier. It provides an output, anytime an input signal is applied.

The NOT, AND, and OR gates are considered to be the three basic logic gates.



* Resistors installed on ETB-6201-A only.

Figure 7-2

Experiment 8
Dual Nature of Logic Gates

Purpose

To demonstrate a combinational Logic function.

To provide practice in using Boolean variables.

To provide practice in evaluating a truth table.

To identify a specific logic function.

Introduction

In this experiment, you will program the binary inputs of zero and one as Boolean variables A and B. Then you will evaluate the circuit's operation by plotting the actions of an LED in a truth table.

As you will see in this experiment, logic gates can be used for more functions than their names imply.

Procedure

1. Connect a jumper wire between TP211 and data switch 1 (TP914).

   Connect a jumper wire between TP216 and data switch 2 (TP913).

   Set the data switches on the trainer to off.

2. Set SW200 to 1, 2, 4, and 5 up. Turn the trainer on and observe the LEDs in block 2.

   Cycle the data switches through the positions shown in the truth table. Data SW1 is A and data SW2 is B.

A	B	X
0	0	
0	1	
1	0	
1	1	

Figure 8-1

3. Plot the truth table outputs assuming that a lit LED indicates a binary 1.

4. Which LED lit?

   ________________.

5. Write the Boolean equation that your truth table describes.

   ________________.

6. What logic function is now being performed?

   ________________.

Summary

The logic function performed in this experiment is the NOR function as indicated by the red LED (L200).

The LED lit only when both Boolean variables equal binary 0.

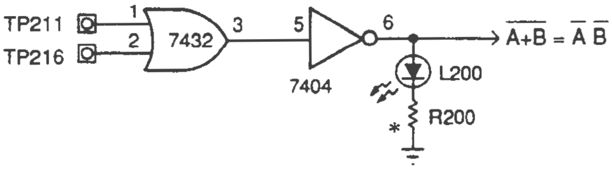
An OR gate provides a 1 in the output anytime any or all of its inputs are equal to 1. In this circuit, the red LED indicates an output only when all of the inputs are equal to zero. This is the same as the output of an OR gate routed through an inverter.

This could also be called the (A + B) NOT function, but is more commonly called the NOR function ($\overline{A + B}$).

The NOR logic function provides a 1 in the output only when all of the inputs equal 0.

Like the AND gate, this circuit provides only one output for the four possible inputs. Unlike the AND gate, its output occurs when the input is 00 instead of 11.

Therefore, the NOR gate is equivalent to a negative logic AND gate.



* Resistors installed on ETB-6201-A only.

Figure 8-2

Experiment 9
Combining Logic Functions

Purpose

To demonstrate a combinational Logic function.

To provide practice in evaluating logic circuits.

To provide practice in evaluating a truth table.

To identify specific logic operations.

Introduction

In this experiment, you will program the binary inputs of zero and one as Boolean variables A and B and evaluate the circuit's operation by plotting the states of an LED in a truth table.

Basic logic gates can be used for more functions than their names imply, as you will see in this experiment. Complex decision making circuits can be designed using the basic logic functions in combinations.

Procedure

1. Connect a jumper wire between TP204 and data switch 1 (TP914).

   Connect a jumper wire between TP205 and data switch 2 (TP913).

   Set the data switches on the trainer to off.

2. Set SW200 to all on. Turn the trainer on and observe the LEDs in block 2.

   Cycle the data switches through the positions shown in the truth table. Boolean variable A is data switch 1 and B is data switch 2.

A	B	X
0	0	
0	1	
1	0	
1	1	

Figure 9-1

3. Plot the truth table outputs by writing in which LEDs are lit for each of the 4 input conditions.

4. What input combinations light the red LED (L200)?

   ______________________ .

   In analog terms, what would you call this type of circuit?

   ______________________ .

   Write the Boolean equation that describes the operation of the red LED.

   ______________________ .

Draw the basic logic symbol that can perform the same function as the red LED.

5. What input combination lights the green LED (L201)?

_____________________.

Write the Boolean term that describes the operation of the green LED.

_____________________.

Draw the basic logic diagram that performs the same function as the green LED.

6. When is the amber LED (L202) lit?

____

What would you call this type circuit?

____

Write the Boolean equation that describes the action required to light the amber LED.

____________________.

Draw the basic logic symbol that performs the same function as the amber LED.

7. What logic function does the clear LED (L203) indicate?

____________________.

Write the Boolean expression that describes the operation of the clear LED.

____________________.

Draw the basic logic symbols that performs the same function as the clear LED.

8. Describe an application for a circuit that performs all four of these functions.

____

____.

Draw one logic circuit that can perform all of the functions indicated by the four LEDs in this experiment and label each LED output.

Once you have drawn your circuit, refer to page 54 Figure 9-3 for the actual circuit used.

Summary

The logic functions performed in this experiment are the A = B, A not equal to B, A > B, and A < B.

The red LED (L200) in this circuit lights whenever the inputs are equal (00 and 11). This is the Exclusive NOR function (ENOR).

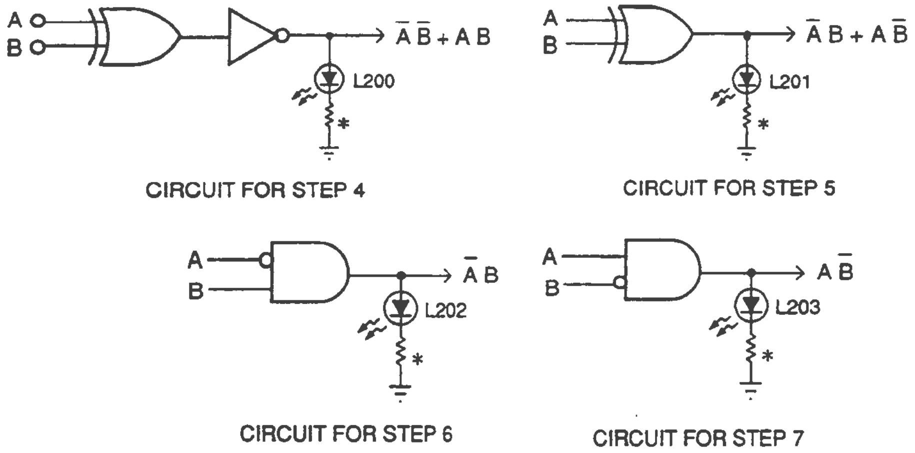
The green LED (L201) is lit anytime the inputs are unequal. This is the Exclusive OR function. More commonly this is referred to as the XOR.

The clear LED (L203) is lit anytime that A > B. This is the inhibited AND function. In this case, the B input is routed through an inverter and then applied to the logic gate.

The amber LED (L202) is lit anytime that A < B. This is another inhibited AND function. In this case, the A input is routed through an inverter and to the logic gate.

This type of circuit is used in automatic sorters or in the loop functions of a computer to make decisions. It is sometimes called a choice box when pictured as part of a flow chart.

Depending on the values of A and B in reference to each other, it selects which branch to route data to, or which step in a program to return to.



CIRCUIT FOR STEP 4

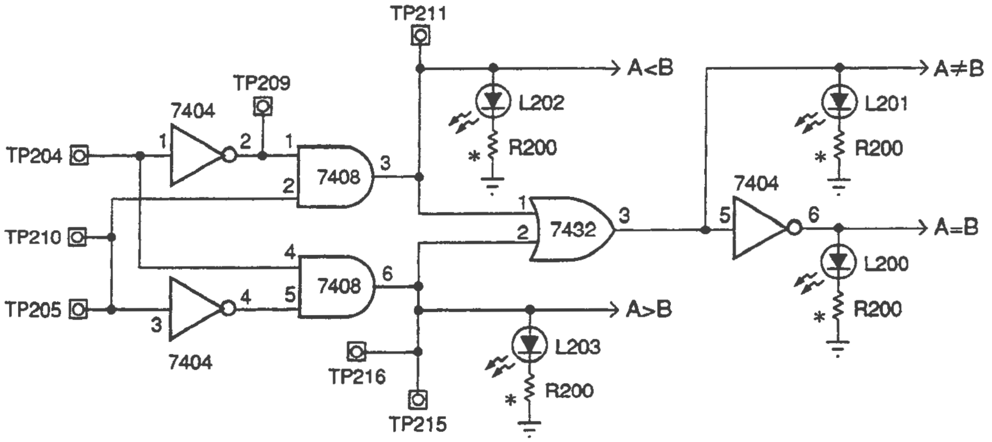
CIRCUIT FOR STEP 5

CIRCUIT FOR STEP 6

CIRCUIT FOR STEP 7

* Resistors installed on ETB-6201-A only.

Figure 9-2



CIRCUIT FOR STEP 8

* Resistors installed on ETB-6201-A only.

Figure 9-3

Experiment 10
Converting NAND to AND

Purpose

To demonstrate a combinational Logic function.

To provide practice in evaluating Boolean variables.

To provide practice in evaluating truth tables.

To identify a particular logic function.

Introduction

In this experiment, you will program the binary inputs of zero and one as Boolean variables A and B and evaluate the circuit's operation by plotting the response of LEDs in a truth table.

Basic logic gates can be used for more functions than their names imply.

Procedure

1. Connect a jumper wire between TP305 and data switch 1 (TP914).

   Connect a jumper wire between TP306 and data switch 2 (TP913).

   Set the data switches on the trainer to off.

2. Set SW300 to 1 and 3 up. Turn the trainer on and observe the LEDs in block 3.

   Cycle the data switches through their four input combinations.

3. Which LED lit?

   ________________.

4. Which input combinations result in a lit LED?

   ________________.

5. Write the Boolean expression that describes the function of the red LED (L301).

   ________________.

6. Draw the logic symbol that your equation describes.

7. Set SW300 to 1, 3, and 5 up. Cycle the data switches through the four input combinations.

8. Write the Boolean term that describes the function indicated by the green LED (L300).

   ________________.

9. Draw the logic symbol that your equation describes.

Summary

The 7400 chip is a Quad-NAND. In steps 1 through 5 the logic function indicated by the red LED (L301) is the NAND function. The red LED is lit anytime both inputs are not ones. This is the complement of the AND function.

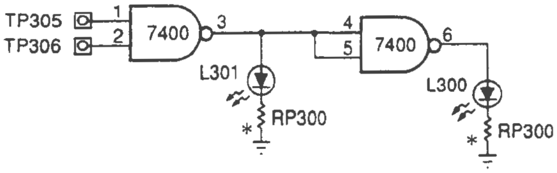
Another way of saying the same thing is to say that this is the AND function inverted (NOTed).

The red LED lit when the Boolean variables equal binary 00, 01, and 10.

The green LED (L300) lit only when both inputs are equal to binary 1. This is the AND function. This is accomplished by converting one of the NAND gates to an inverter by shorting its inputs together.

Therefore, the NAND function, when routed through an inverter becomes a double inverted AND. It is equivalent to a standard AND gate like the 7408 you used in an earlier experiment.

In this experiment you used a standard four 2-input NAND package to perform both the NAND and AND logic functions.



* Resistors installed on ETB-6201-A only.

Figure 10-1

Experiment 11
Equivalent Logic Gates (NAND to AND)

Purpose

To demonstrate a combinational Logic function.

To provide practice in evaluating truth tables.

To prove a DeMorgan Theorem.

Introduction

In this experiment you will program the binary inputs of zero and one as Boolean variables A and B and evaluate the circuit's operation by plotting the responses of an LED in a truth table.

As you have seen, the same logic function can be performed by more than one logic circuit. When the same logic function is performed by more than one circuit, the circuits are said to be equivalent circuits.

In this experiment, you will prove both the dual nature of logic gates and that this circuit performs the same function as another chip used in an earlier experiment.

Procedure

1. Connect a jumper wire between TP303 and data switch 1 (TP914).

   Connect a jumper wire between TP304 and data switch 2 (TP913).

   Set the data switches on the trainer to off.

2. Set SW300 to 1 and 4 up. Set SW301 to 1 up. Turn the trainer on and observe the LEDs in block 3.

   Cycle the data switches through their four input combinations.

3. Plot the truth table outputs assuming that a lit LED indicates a binary 1. Data SW1 is A and data SW2 is B.

A	B	X
0	0	
0	1	
1	0	
1	1	

Figure 11-1

4. Which input or inputs cause L303 to light?

   ____________________.

5. Which LED lights for mismatched inputs?

   ____________________.

6. Write the Boolean equations that cause L306 to light.

   ____________________.

7. Draw the logic circuit that your equations describe.

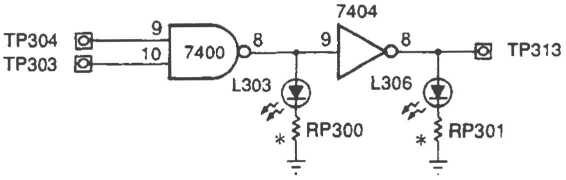
Summary

The amber LED (L303) is the NAND function. It is lit for 00, 01, and 10.

The 7400 chip provides the NAND function, but the logic function indicated by L306 is the AND function. L306 is lit only when both inputs are ones.

In other words, when the NAND gate's output is inverted (NOTed), it performs the AND function. This is because any even number of NOTs result in the original Boolean expression. The NAND gate provides the first NOT and a gate from the 7404 provides the second NOT.

In a previous experiment, a second NAND gate was used to provide the second NOT. This proves that when you tie the inputs of a NAND gate together, it functions as (is equivalent to) an inverter.



* Resistors installed on ETB-6201-A only.

Figure 11-2

Experiment 12
Converting NOR to OR

Purpose

To demonstrate a combinational Logic function.

To provide practice in evaluating a truth table.

To prove a DeMorgan Theorem.

Introduction

In this experiment, you will program the binary inputs of zero and one as Boolean variables A and B and evaluate the circuit's operation by plotting the state of the LED in a truth table.

The same logic function can be performed by more than one logic circuit. When the same logic function is performed by more than one circuit, the circuits are said to be equivalent circuits.

In this experiment, you will again prove both the dual nature of logic gates and that this circuit performs the same function as another chip in an earlier experiment.

Procedure

1. Connect a jumper wire between TP309 and data switch 1 (TP914).

   Connect a jumper wire between TP311 and TP312.

   Connect a jumper wire between TP310 and data switch 2 (TP913).

   Set the data switches on the trainer to off.

2. Set SW300 to 2, 6, and 7 up. Turn the trainer on and observe the LEDs in block 3.

   Cycle the data switches through the positions shown in the truth table. Data SW1 is A and data SW2 is B.

A	B	X
0	0	
0	1	
1	0	
1	1	

Figure 12-1

3. Plot the truth table outputs assuming that a lit LED indicates a binary 1. List the lit LED in the truth table.

4. Which color LED lights with an input of 00?

   ____________________.

5. Which color LED lights with an input of 01?

   ____________________.

6. Which color LED lights with an input of 10?

   ____________________ .

7. Which color LED lights with an input of 11?

   ____________________ .

8. Which input or inputs result in a lit green LED?

   ____________________ .

9. Write the Boolean equations that describes your truth table plots for L304 and L305.

   ____________________ ____________________ .

10. Draw the basic logic symbols that your equation describes.

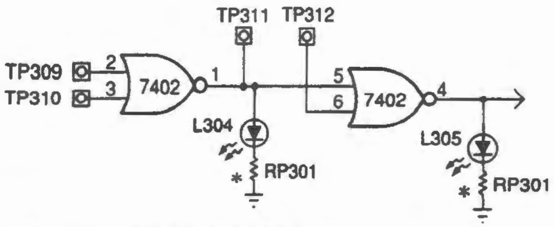
Summary

The 7402 is a Quad-NOR chip, but the logic function indicated by the green LED (L305) is the OR function. The green LED is lit anytime any of the inputs equal 1.

The red LED (L304) is lit only when both inputs are 0. This is the NOR function. The NOR function is the inverted OR function.

In this circuit, using two of the four 2-input NOR gates provides both the NOR and OR functions. The OR and NOR gates are complements of each other.

In an earlier experiment, you used a NAND gate (7400) as an inverter. This was accomplished by tieing its inputs together. The NOR gate (7402) also performs the NOT function when its inputs are tied together.



* Resistors installed on ETB-6201-A only.

Figure 12-2

Experiment 13
Equivalent Logic Gates (NOR to OR)

Purpose

To demonstrate another equivalent combinational Logic function.

To provide practice in evaluating truth tables.

To prove a DeMorgan Theorem.

Introduction

In this experiment, you will program the binary inputs of zero and one as Boolean variables A and B and evaluate the circuit's operation by plotting the states of an LED in a truth table.

The same logic function can be performed by more than one logic circuit. When the same logic function is performed by more than one circuit, the circuits are said to be equivalent circuits.

In this experiment, you will again prove both the dual nature of logic gates and that this circuit performs the same logic function as another chip in an earlier experiment.

Procedure

1. Connect a jumper wire between TP300 and TP907 (+5v).

   Connect a jumper wire between TP307 and data switch 1 (TP914).

   Connect a jumper wire between TP308 and data switch 2 (TP913).

   Set the data switches on the trainer to off.

2. Set SW300 to 1, 2, and 8 up. Turn the trainer on and observe the LEDs in block 3.

   Cycle the data switches through the positions shown in the truth table.

3. Plot the truth table outputs assuming that a lit LED indicates a binary 1. Data SW1 is A and data SW2 is B.

A	B	X
0	0	
0	1	
1	0	
1	1	

Figure 13-1

4. Which input or inputs result in a lit LED.

5. Which LED lights?

6. Write the Boolean equation that describes your truth table plots.

7. Draw the basic logic symbol that your equation describes.

Summary

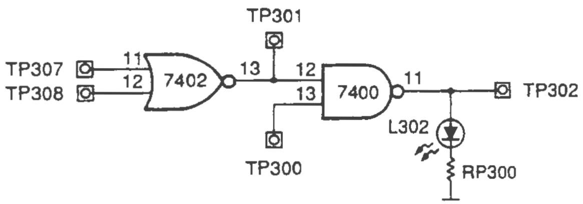
The 7402 is a Quad-NOR chip, but the logic function indicated by the amber LED (L302) is the OR function. The amber LED is lit when any of the inputs equal 1.

In this circuit, using one of the four 2-input NOR gates (7402) and one of the four 2-input NAND (7400) gates, the logic circuit provides the OR function. The OR and NOR gates are compliments of each other. In this experiment, you used A NAND gate as an inverter to compliment the NOR function of the 7402.

In Experiment 12, you used a NOR gate for the NOR function and a second NOR gate for the inverter function by tieing its inputs together. In this experiment, you combined a NOR gate and a NAND gate to produce an equivalent OR circuit.

Up to this point in the experiments, you have seen that by using NOR and NAND gates you can provide the NOT, AND, and OR functions. This is in addition to the NOR and NAND functions for which the 7402 and 7400 were designed.

Therefore, by combining NOT, AND, OR, NOR, and NAND gates it is possible to provide a variety of unique Boolean equations. These equations can be used to describe a wide variety of specific logic functions.



* Resistors installed on ETB-6201-A only.

Figure 13-2

Experiment 14

Comparing the 4001 to the 7402

Purpose

To demonstrate another equivalent combinational logic function.

To provide practice in evaluating truth tables.

To prove DeMorgan's Theorems.

Introduction

In this experiment, you will program the binary inputs of zero and one as Boolean variables A and B and evaluate the circuit's operation by plotting the states of an LED in a truth table.

The same logic function can be performed by more than one logic circuit. When the same logic function is performed by more than one circuit, the circuits are said to be equivalent circuits.

In this experiment, you will prove both the dual nature of logic gates and that this circuit performs the same function as another chip in an earlier experiment.

Procedure

1. Connect a jumper wire between TP317 and data switch 1 (TP914).

   Connect a jumper wire between TP318 and data switch 2 (TP913).

   Set the data switches on the trainer to off.

2. Set SW301 to 1 and 8 up. Turn the trainer on and observe the LEDs in block 3.

   Cycle the data switches through the positions shown in the truth table. Data SW1 is A and data SW2 is B.

3. Plot the truth table outputs assuming that a lit LED indicates a binary 1.

A	B	X
0	0	
0	1	
1	0	
1	1	

Figure 14-1

4. Write the Boolean term or terms that result in a lit LED.

   ________________.

5. Which LED lights?

   ________________.

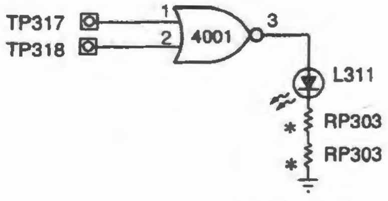
6. Draw the basic logic symbol that your equation describes.

Summary

The 4001 is another Quad-NOR chip similar to the 7402 used in an earlier experiment. However, if you examine the pin outs of both the 4001 and 7402, you will see that the circuit configurations are not the same even though they perform the same function. The pin outs are not the same even though both chips are Quad-NORs. Therefore, before wiring a solid state component into a circuit, consult the manufacturer's specification sheet or wiring diagram.

DO NOT ASSUME THAT ALL IC CHIPS FROM ALL MANUFACTURERS ARE INTERNALLY WIRED THE SAME. THEY ARE NOT!

In this experiment, the amber LED (L311) indicates the NOR function. In other words, the NOR logic circuit provides an output only when there are no inputs.



* Resistors installed on ETB-6201-A only.

Figure 14-2

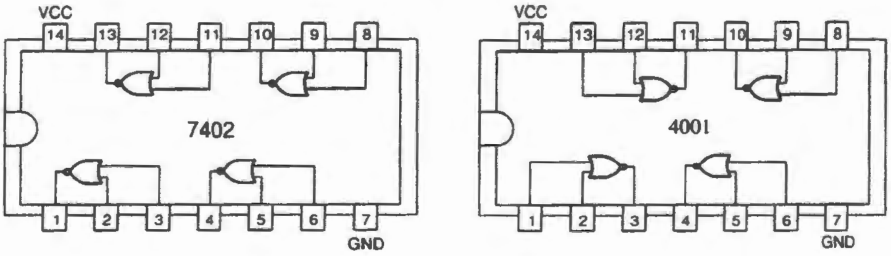


Figure 14-3

Experiment 15
Combining the 4001 and 7404

Purpose

To demonstrate another equivalent combinational Logic function.

To provide practice in evaluating truth tables.

To prove DeMorgan's Theorems.

Introduction

In this experiment, you will program the binary inputs of zero and one as Boolean variables A and B and evaluate the circuit's operation by plotting the states of an LED in a truth table.

The same logic function can be performed by more than one logic circuit. When the same logic function is performed by more than one circuit, the circuits are said to be equivalent circuits.

In this experiment, you will prove both the dual nature of logic gates and that this circuit performs the same function as another chip in an earlier experiment.

Procedure

1. Connect a jumper wire between TP317 and data switch 1 (TP914).

   Connect a jumper wire between TP318 and data switch 2 (TP913).

   Set the data switches on the trainer to off.

2. Set SW301 to 1, 7, and 8 up. Turn the trainer on and observe the LEDs in block 3.

   Cycle the data switches through the positions shown in the truth table. Data SW1 is A and data SW2 is B.

3. Plot the truth table outputs assuming that a lit LED indicates a binary 1. Plot the outputs by color of lit LED.

A	B	X
0	0	
0	1	
1	0	
1	1	

Figure 15-1

4. Write the Boolean term or terms that result in L308 lit.

   ________________ .

5. Which LED or LEDs light?

   ________________ .

6. Write a separate Boolean equation that describes the action of each LED that lights.

   ________________ ________________ ________________ .

7. Draw and label the logic circuits that your equations describe.

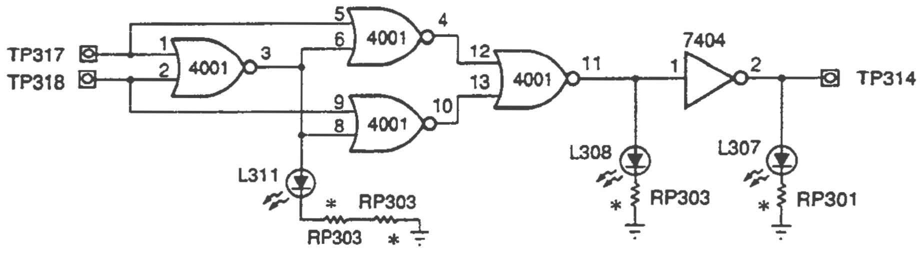
Summary

The red LED (L308) lights with an input of 00 or 11. In other words, L308 lights only when both inputs are equal. Thus, this logic circuit performs the XNOR function. NOTE: The circuit on the ETB-6201 board may appear to operate like an AND function. That's because LED L311 uses more current than the 4001 CMOS gate, pin 3, can supply. As a result, the voltage at pins 6 and 8 may not reach a logic 1 level, and the output at pin 11 will only go high when both TP317 and TP318 are high. Set SW301 to 8 down if this occurs. L308 and L307 will then operate properly.

The green LED (L307) is the complement of the red LED. Thus, the green LED indicates the XOR function. This is the equivalent of the XNOR function inverted.

The amber LED (L311) still indicates the NOR function because it is lit only when both inputs are equal to 0. This could represent a negative logic NAND gate.

This equivalent NOR, XNOR, and XOR circuit uses the 4001 Quad-NOR in conjunction with the 7404 Hex-Inverter.



* Resistors installed on ETB-6201-A only.

Figure 16-2

Experiment 16
The Basic NAND Gate

Purpose

To demonstrate another equivalent combinational Logic function.

To provide practice in evaluating truth tables.

To prove DeMorgan's Theorems.

Introduction

In this experiment, you will program the binary inputs of zero and one as Boolean variables A and B and evaluate the circuit's operation by plotting the states of an LED in a truth table.

The same logic function can be performed by more than one logic circuit. When the same logic function is performed by more than one circuit, the circuits are said to be equivalent circuits.

In this and the next experiment, you will prove both the dual nature of logic gates and that this circuit performs the same function as another chip in an earlier experiment.

Procedure

1. Connect a jumper wire between TP319 and data switch 1 (TP914).

   Connect a jumper wire between TP320 and data switch 2 (TP913).

   Set the data switches on the trainer to off.

2. Set SW301 to 1, 2, and 4 up. Turn the trainer on and observe the LEDs in block 3.

   Cycle the data switches through the positions shown in the truth table. Data SW1 is A and data SW2 is B.

3. Which LED is lit?

   ________________.

4. Plot the truth table outputs assuming that a lit LED indicates a binary 1.

5. Write the inputs that result in a lit LED.

   ________________.

6. Which color LED or LEDs light?

   ________________.

A	B	X
0	0	
0	1	
1	0	
1	1	

Figure 16-1

7. Write a Boolean equation that describes the action of each LED that lights.

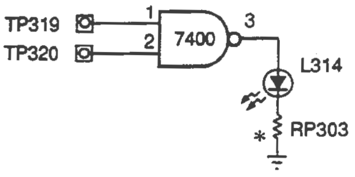
   ________________.

8. Draw the logic circuit that the equation describes.

Summary

The red LED, L314, lights with inputs of 00, 01, and 10. In other words, L314 lights for all input conditions except 11. Thus, this circuit is the same as the AND gate inverted. We call this type of circuit an AND gate NOTed, or simply NAND gate.

Since the 7400 is a Quad-NAND, all four of its gates can perform this function.



* Resistors installed on ETB-6201-A only.

Figure 16-2

Experiment 17
Combining the 7400 and 7404

Purpose

To demonstrate another equivalent combinational Logic function.

To provide practice in evaluating truth tables.

To prove DeMorgan's Theorems.

Introduction

In this experiment, you will program the binary inputs of zero and one as Boolean variables A and B and evaluate the circuit's operation by plotting the states of an LED in a truth table.

The same logic function can be performed by more than one logic circuit. When the same logic function is performed by more than one circuit, the circuits are said to be equivalent circuits.

In this experiment, you will prove both the dual nature of logic gates and that this circuit performs the same function as another chip in an earlier experiment.

Procedure

1. Connect a jumper wire between TP319 and data switch 1 (TP914).

   Connect a jumper wire between TP320 and data switch 2 (TP913).

   Set the data switches on the trainer to off.

2. Set SW301 to 1, 2, and 6 up. Turn the trainer on and observe the LEDs in block 3.

3. Which LED is now lit?

   ____________________ .

4. Cycle the data switches through the positions shown in the truth table. Data SW1 is A and data SW2 is B.

5. Plot the truth table outputs assuming that any lit LED indicates a binary 1. Plot the outputs by color of LED.

A	B	X
0	0	
0	1	
1	0	
1	1	

Figure 17-1

6. Which LED or LEDs light?

   ____________________ .

7. Write a separate Boolean equation that describes the action of each LED that lights.

   ____________________ ____________________ .

8. Draw the basic logic gates that the equation describes.

9. Turn SW301 switch 4 on (up) (leave 1, 2, and 6 up) and recycle the data switches through their 4 possible input combinations while observing the LEDs.

10. Which input combination cause both a green and red LED to be lit at the same time?

11. Which input combination causes two red LEDs to be lit at the same time?

12. Draw the logic symbols that the truth table describes.

Step 10 Step 12

13. What is the function of L314?

______________ .

Summary

In this experiment the 7400 is combined with a 7404 hex inverter.

The red LED (L309) lights with inputs 00 and 11. In other words, the red LED (L309) lights when the two inputs are equal. This type circuit is sometimes called an equality detector or more commonly the XNOR (Exclusive NOR) logic function.

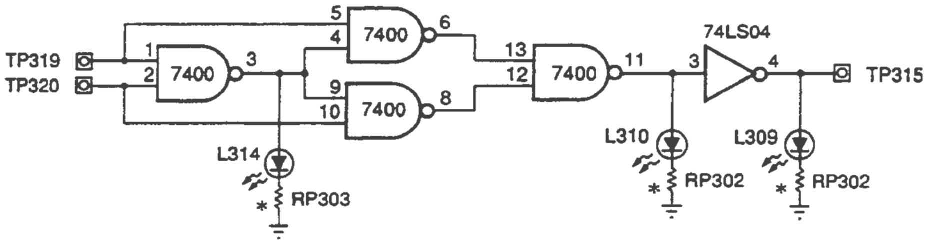
The green LED (L310) lights with inputs 01 and 10. This is the output of an XOR (Exclusive OR). It provides an output only when the inputs are not equal. This type circuit is also referred to as an inequality detector.

The green LED (L310) and the red LED (L309) are complements of each other. Therefore, if the red LED indicates the XNOR function, the green LED indicates the XOR function.

The output indicated by the red LED is simply inverted, by one of the gates of the 7404 hex inverter, to provide the output indicated by the green LED.

The red LED (L314) indicates an output with inputs of 00, 01, and 10. This is the output of a standard NAND gate.

In this experiment, with dip switches 1, 2, 4, and 6 up and the inputs applied to the 7400 chip the circuit provides the NAND, XOR, and XNOR functions. These functions are supplied as separate outputs as indicated by the LEDs.



* Resistors installed on ETB-6201-A only.

Figure 17-2

Experiment 18
The 7486 Chip

Purpose

To demonstrate another equivalent combinational Logic function.

To provide practice in evaluating truth tables.

To prove DeMorgan's Theorems.

Introduction

In this experiment, you will program the binary inputs of zero and one as Boolean variables A and B and evaluate the circuit's operation by plotting the states of an LED in a truth table.

The same logic function can be performed by more than one logic circuit. When the same logic function is performed by more than one circuit, the circuits are said to be equivalent circuits.

In this experiment, you will prove both the dual nature of logic gates and that this chip performs the same function as another logic circuit demonstrated in an earlier experiment.

Procedure

1. Connect a jumper wire between TP321 and data switch 1 (TP914).

   Connect a jumper wire between TP322 and data switch 2 (TP913).

   Set the data switches on the trainer to off.

2. Set SW301 to 3 and 5 up. Turn the trainer on and observe the LEDs in block 3. Cycle the data switches through the positions shown in the truth table. Data SW1 is A and data SW2 is B.

3. Plot the truth table outputs by LED color. Assume that a lit LED indicates a binary 1.

4. Write the input combination that results in a lit LED.

______________________.

A	B	X
0	0	
0	1	
1	0	
1	1	

Figure 18-1

5. Which LED or LEDs light?

______________________.

6. Write the Boolean equation that describes the action of each LED that lights.

______________________.

7. Draw the logic circuit that the equation describes.

8. Turn dip switch SW301 position 1 on and recycle the data switches through the input combinations while observing the LEDs.

9. Write the Boolean expressions that describes the outputs of this circuit.

____________________.

10. Draw the logic diagram that the equations describe.

Summary

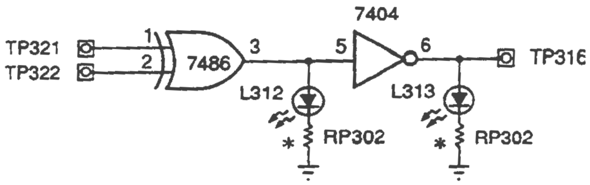
In this experiment, the 7486 Quad-Exclusive OR is combined with a 7404 hex inverter.

The green LED (L312) lights each time the inputs are mismatched. This proves that the 7486 chip provides the Exclusive OR function.

When Dip switch 1 is on, the output from the green LED is routed through an inverter (1/6 of the 7404) to provide a complement function.

The red LED (L313) lights with inputs 00 and 11. In other words, the red LED lights when the inputs are equal. Thus, this type circuit is sometimes called an equality detector or more commonly the XNOR logic function.

In this experiment, you used a specific function chip (Exclusive OR—7486) to perform a function that you had already seen in two earlier experiments. One experiment used NOR gates to provide the function. The other circuit used NAND gates to perform the Excluse OR function. Again, an inverter is used to provide complimentary outputs. The outputs were indicated separately by the green (L312) and red (L313) LEDs.



* Resistors installed on ETB-6201-A only.

Figure 18-2

Experiment 19
Negated Gates

Purpose

To demonstrate a binary encoder.

To demonstrate the use of inverters in the input data line.

To prove the equivalent circuits in Appendix A of Unit 3.

Introduction

In this experiment, you will use inverters in the input data lines. When the inputs of a logic gate are inverted they are said to be negated. This is a term that designates the placement of the inverter. When the inverter is used at the output it is called an inverter.

When the inverter is used in an input line it still inverts the data, but the gate is said to have a negated input. Place an inverter on the output of that gate and you have converted the positive logic of that gate into negative logic.

One or more inputs of a basic logic gate can be inverted (negated) to cause the logic gate to pass a preselected numerical value. For example, the standard AND gate passes only the input 11. An inverter in the A input line of an AND gate causes the gate to pass 01 instead of 11.

The AND gate is then said to be encoded to accept the input code 01 or $\bar{A}B$.

The use of the inverter in the input line is referred to as "inhibiting the input" in many computer text books.

Procedure

1. Connect the jumper wires as listed below.

   From data switch 1 (TP914) to TP200 (pin 13 of U200).

   From data switch 2 (TP913) to TP203 (pin 11 of U200).

   TP202 (pin 12 of U200) to TP206 (pin 13 of U201).

   TP 201 (pin 10 of U200) to TP207 (pin 12 of U201).

   TP208 (pin 10 of U201) to TP905 (L_4 on the main trainer).

2. Set SW200 to 1, 2, 3, and 4 high.

3. Turn the trainer on and observe L_4 while you cycle through the input combinations.

4. Which of the input combinations cause L_4 to light?

   ____________________________.

5. Which equivalent circuit provides the same output without using external inverters?

   ____________________________.

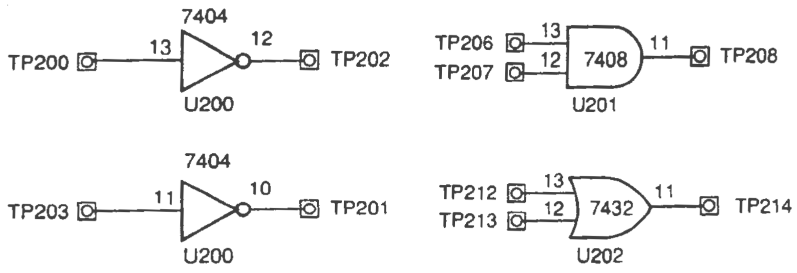


Figure 19-1

6. Move the jumpers wires from:

   TP206 to TP212 (pin 13 of U202).

   TP207 to TP213 (pin 12 of U202).

   TP208 to TP214 (pin 11 of U202).

7. Cycle through the four possible input combinations.

8. Which of the four input combinations now cause L_4 to light?

   ___________________________.

9. Which equivalent circuit provides the same output without using external inverters?

   ___________________________.

10. Move the jumper wires from:

    TP212 to TP300 (pin 13 of U300).

    TP213 to TP301 (pin 12 of U300).

    TP214 to TP302 (pin 11 of U300).

11. Set SW200 to 1 and 2 on. Set SW300 to 1 on.

12. Cycle through the input combinations.

13. Which of the input combinations now cause L_4 to light?

    ___________________________.

14. **Which equivalent circuit provides the same output without using external inverters?**

______________________________.

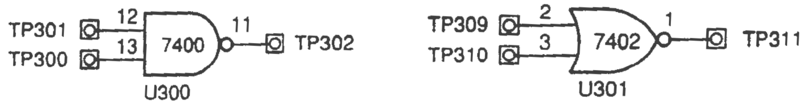


Figure 19-2

15. Move the jumper wires from:

TP301 to TP307 (pin 12 of U301

TP302 to TP301 (pin 13 of U301).

TP300 to TP308 (pin 11 of U301).

Turn SW300 switch 2 on.

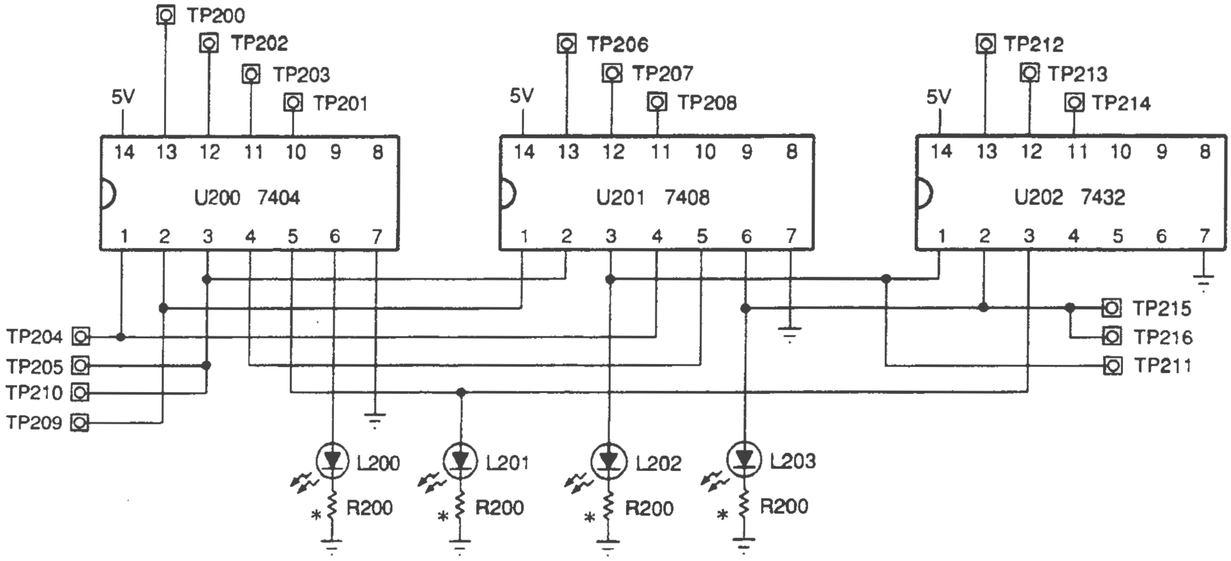
16. Cycle through the input combinations.

17. Which of the input combinations now cause L_4 to light?

______________________________.

18. What is the equivalent circuit that provides the same output without using external inverters?

______________________________.



* Resistors installed on ETB-6201-A only.

Figure 19-3

Summary

By selectively combining inverters with other logic gates it is possible to select any input to pass to the output.

This process is usually called encoding, when the inverters are applied to the inputs of logic gates. It is also called decoding in certain applications.

Steps 1–5
The double negated AND gate (inverters in both input lines) provides an output when both inputs are equal to zero. This also describes the NOR function.

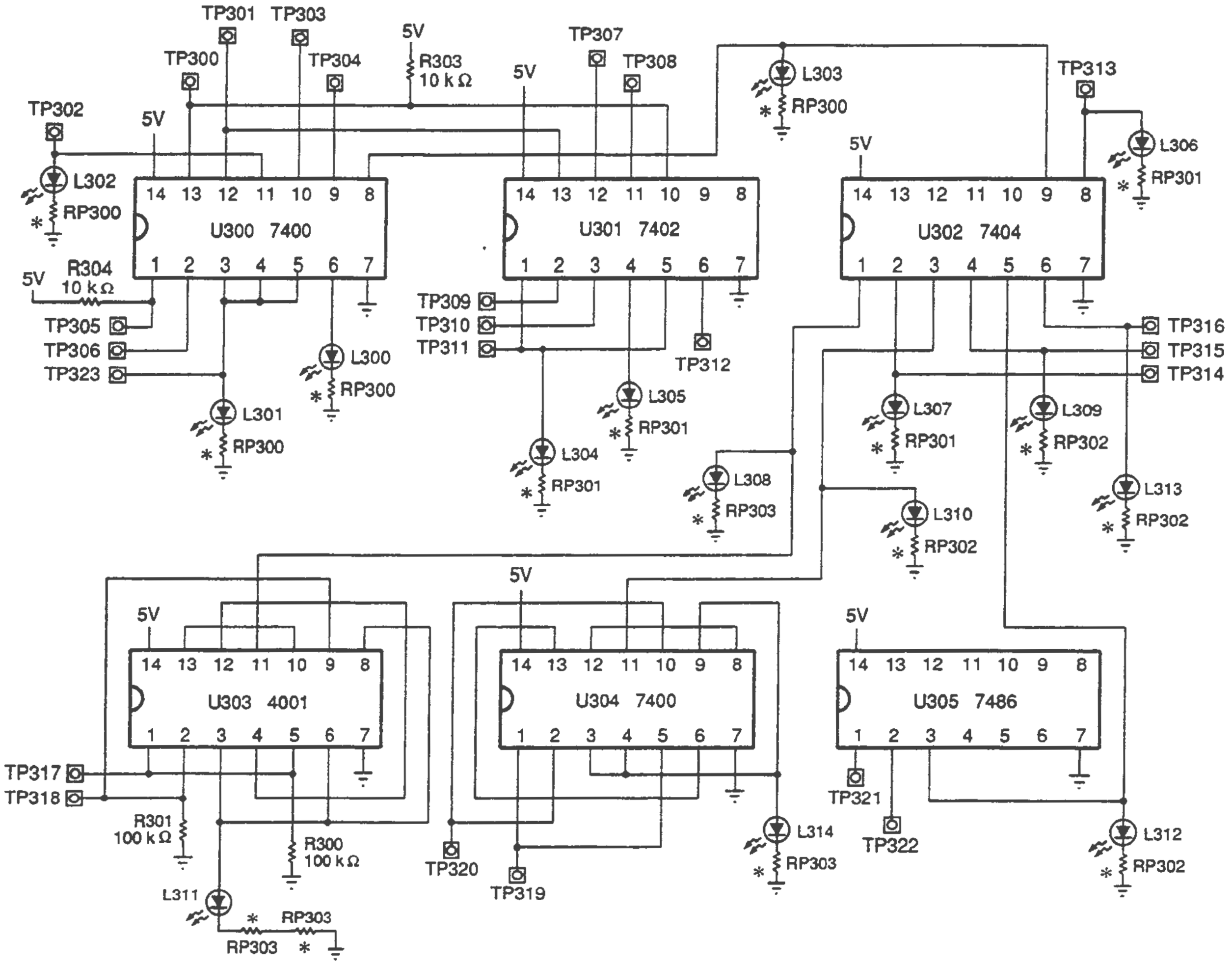
A positive logic NOR gate is the same as a negative logic NAND gate because they both provide the same output (an output when both inputs are low.

Steps 6–9
The double negated OR (negative logic NOR) gate provides an output for all inputs except 11. This is the same output that the NAND gate provides.

Steps 10–14
The double negated NAND (negative logic AND) gate provides an output anytime A or B equals 1 . This is the same as the OR function.

Steps 15–18
The double negated NOR (negative logic OR) gate provides an output when both A and B equal 1. This is the same as the AND function.

When you are satisfied that you understand the information presented in this experiment, turn the trainer off and remove all jumper wires and set all dip switches low.



* Resistors installed on ETB-6201-A only.

Figure 19-4

Experiment 20
The 7475 Chip

Purpose

To demonstrate another device used to store binary bits.

To illustrate 4-bit storage

Introduction

In this experiment, you will program the binary inputs of zero and one as Boolean variables A, B, C, and D. Then, you will evaluate the circuit's operation by observing the states of the LEDs.

In this experiment, you will examine the operation of a quad D-type flip-flop, also known as a quad bistable latch. In the experiment using the bistable multivibrator in block 1, you had a device capable of storing a single binary bit.

The bistable multivibrator in block 1 is an RS-type flip-flop. The term RS means set/reset.

By cascading bistable devices you can store as many binary bits as there are bistable stages.

The quad D-type flip-flop (bistable latch) can store 4 binary bits of data. In this case, assume that the bits refer to the binary numbers 0000 through 1111.

Procedure

1. Connect jumper wires between:

   TP400 (pin 2 of the 7475 IC) and data switch 1 (TP914).

   TP401 (pin 3 of the 7475 IC) and data switch 2 (TP913).

   TP402 (pin 6 of the 7475 IC) and data switch 3 (TP912).

   TP403 (pin 7 of the 7475 IC) and data switch 4 (TP911).

   TP404 (pin 4 of the 7475 IC) and TP909.

   Data switch 4 controls the LSB (least significant bit).

2. Set SW400 to 1 up.

3. Turn the trainer on and observe the LEDs above the 7475 (U400) chip in block 4.

4. Cycle the data switches through the positions shown in the truth table.

5. Record in the truth table (Figure 20-1) the LEDs that are lit for each line of switch positions.

INPUTS				OUTPUTS			
SW1	SW2	SW3	SW4	L400	L401	L402	L403
0	0	0	0				
0	0	0	1				
0	0	1	0				
0	0	1	1				
0	1	0	0				
0	1	0	1				
0	1	1	0				
0	1	1	1				
1	0	0	0				
1	0	0	1				
1	0	1	0				
1	0	1	1				
1	1	0	0				
1	1	0	1				

Figure 20-1

6. What did you observe about the LEDs response time as you cycled the data switches?

   ____

7. Move the jumper wire from TP909 to TP910. Move data switches 2 and 3 up.

8. What did you notice about the LED response of L401 and L402? ________

   ____

9. Cycle the A logic switch.

10. What happened to L401 and L402? ____________________

    ____

11. Set SW400 to 1 and 2 up. Cycle data switches 2 and 3.

12. Did the LEDs respond immediately or did you have to cycle the A logic switch to obtain data storage? ____________________

13. What is the positional weight of L402? ____________________

14. Reset SW400 so that only switch 1 is up. Set the clock to 1Hz. Then, move the jumper wire from TP910 to TP906 (the clock input).

15. Cycle the data switches a few times while observing the LEDs above the 7475 chip.

16. Did you notice a delay in the LED's response to the changed data switch?

______________________________.

17. What caused the delay (if any) that you observed.

____ .

18. How many separate pieces of data can be stored in a 4-bit binary register.

______________________________.

19. What is the largest equivalent decimal number that can be stored in a 4-bit binary register?

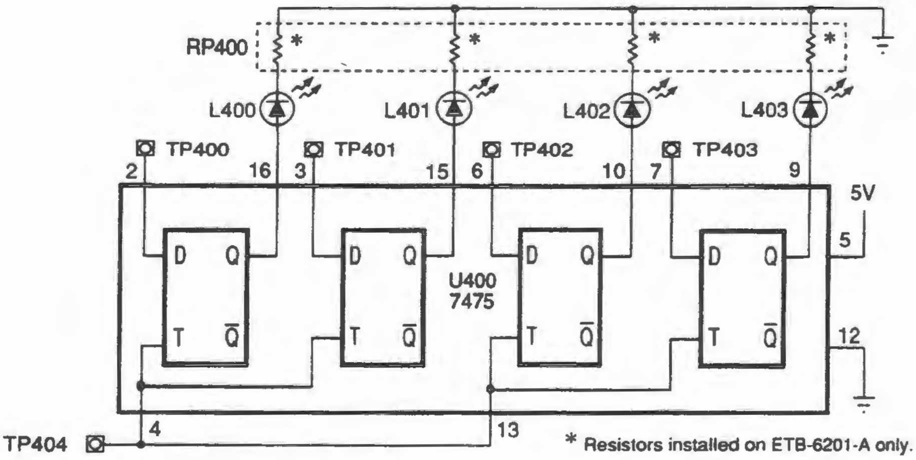
______________________________.

20. What is the minimum propogation delay for programming this 4-bit register using the clock as an input?

______________________________.

21. What type of data routing is used to program this D-Type flip-flop register?

______________________________.



* Resistors installed on ETB-6201-A only.

Figure 20-2

Summary

In this experiment, you used the 7475 D-type flip-flop (quad bistable latch) as a 4-bit programmable register.

You should have noticed that for the register to be programmable, the T (trigger/toggle) input—also known as the C (enable) input—has to be held high (TP404 pins 4 and 13 of the chip).

When TP404 is connected to the A(NOT) terminal TP909 pin 4 is high and the LEDs respond to the data changes as you make them.

When TP404 is connected to TP910, pins 4 and 13 are low until the A logic switch is cycled. The A logic terminal TP910 is high only when the switch is held down. Thus, the data is programmed (loaded) by the A logic switch. Once loaded, releasing the logic switch should have no effect on the stored data.

When SW400 switch 2 is high, the chip responds immediately to the data whether it is connected to the A or A(NOT) logic terminal. This happens because pins 4 and 13 are held high by the switch.

When you connected the clock input to pins 4 and 13 of the 7475 and switched off position 2 of SW400, you are controlling the time when the latches are enabled. You should have noticed an occasional delay when you cycled the data switches. That delay occurs whenever the clock is low and you move a switch. As soon as the clock goes high, the LED will respond as the data is latched.

A 4-bit register can respond to 16 changes. The four D inputs represent four separate variables. Since each Boolean variable can have two values (0 and 1) the formula is 2^4, which is equal to 16. Therefore, 0000 through 1111 can be represented by four binary bits, as shown below.

$$1 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$$

You should have remembered that any number raised to the zero power is equal to 1. You should also know that the 4-bit binary weighted code is 8, 4, 2, 1.

Therefore, the largest number that can be stored is binary 1111, which is equivalent to decimal 15.

Since the inputs are in parallel, the register is said to be parallel loaded. When using parallel loading, the propagation delay is equal to the transient response time of the slowest gate because all of the gates change state at the same time.

Experiment 21
The 7476 Chip

Purpose

To demonstrate another device used to store binary bits.

To illustrate a JK flip-flop.

Introduction

In this experiment, you will examine the operation of the 7476 dual JK-type flip-flop. The JK flip-flop is another device capable of storing binary data. By cascading JK flip-flops you can store as many binary bits as there are bistable stages.

Because of varying manufacturing specifications, and the trend in making IC chips respond to faster and faster input signals, is causing some problems when JK flip-flops are operated below 40 Hz. As a result, this and other experiments using JK flip-flops may not always work exactly as described. Changes to the circuits on the ETB-6201-A circuit board have reduced these potential problems to the point where you should experience no trouble.

Procedure

1. Connect a jumper wire between TP405 and data switch 1 (TP914).

   Connect a jumper wire between TP406 and data switch 2 (TP913).

   Connect a jumper wire between TP407 and TP910.

   Connect a jumper wire between TP408 and TP907.

   Make sure the data switches are switched low.

2. Set SW400 to 4 on.

   Turn the trainer on and observe the LEDs in block 4.

3. Which LEDs are lit?

   ______________.

4. Cycle the B logic slide switch. Which color LEDs in block 4 are now lit?

   ______________.

5. Set data switch 1 high. Cycle the A logic switch. What happens to the LEDs?

   ____.

6. Set data switch 1 low and data switch 2 high. Cycle the A logic switch. How do the LEDs react to this change?

   ____.

   The B logic switch can be used to reset the flip-flop if you wish to repeat steps 4-6.

7. Cycle the A logic switch several times.

   Do the LEDs change states on the leading or trailing edge of the input pulse?

   ______________.

8. What is the relationship between the green and red LEDs that are changing states?

   ______________.

9. Set SW400 to 4 and 5 on.

10. Which LEDs are now lit?

    ______________.

11. Cycle the B logic switch.

12. Which color LEDs are now lit?

______________.

13. Set data switch 1 and 2 low.

14. Cycle the A logic switch.

15. Does any LED change states?

______________.

16. Set data switch 1 high.

17. Cycle the A logic switch.

18. Does any LED change states?

______________.

Explain why this happens:

____

19. Set data switch 1 low and data switch 2 high.

20. Cycle the A logic switch.

Which LEDs changed states?

______________.

21. Cycle the A logic switch three times.

22. What is the condition of the JK flip-flops at this time?

______________.
Set/Reset

23. Cycle the A logic switch four times.

24. Explain why the flip-flops reacted as they did in step 23.

____.

25. Set data switch 1 high and data switch 2 low.

26. Cycle the A logic switch four times.

27. Explain why the flip-flops reacted as they did in step 26.

____.

28. Cycle the A-slide switch four more times.

29. Explain why the flip-flops reacted as they did.

____.

30. Set data switch 1 high and data switch 2 low. What is the function of the A logic switch?

____.

31. Set data switch 2 high and data switch 1 low. What is the function of the A logic switch?

____.

32. Cycle the B logic slide switch.

33. What is the function of the B logic switch?

____.

Did the LEDs react to the leading or trailing edge of the input pulse?

B switch ________________.
A switch ________________.

What polarity change caused switching?

________________.

34. Move the jumper wire from TP910 to TP909. Set data switch 2 high and data switch 1 low.

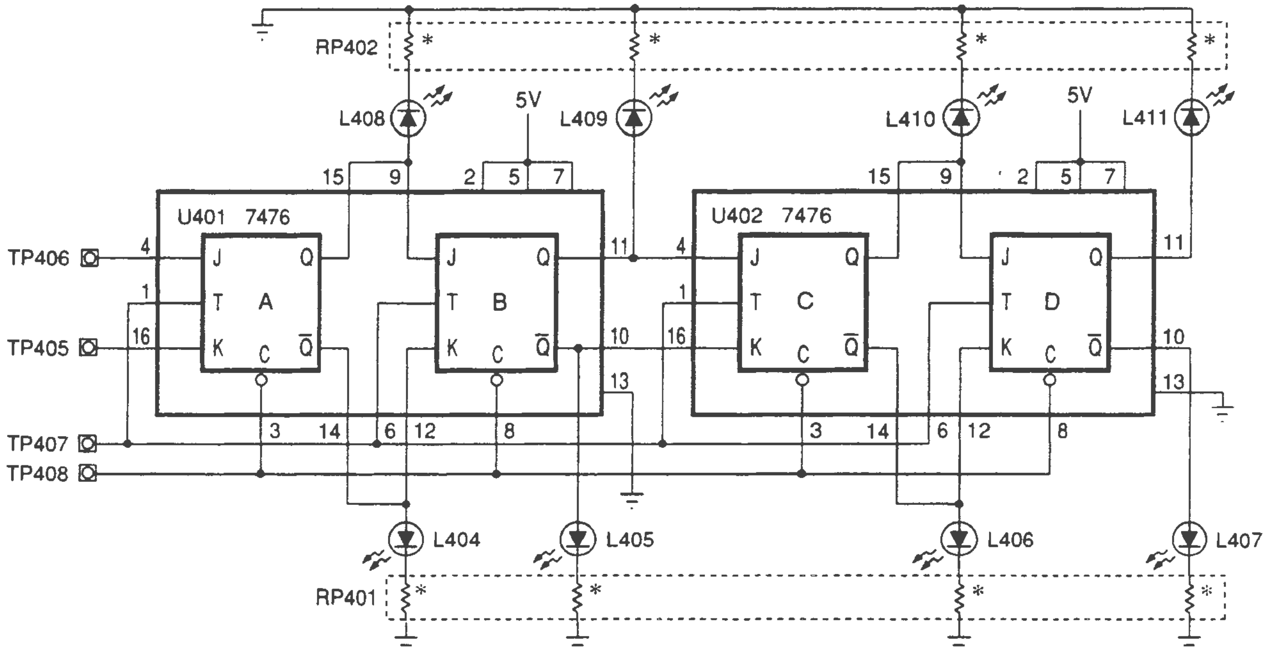
35. Alternately cycle the A and B logic switches.

Do the red LEDs (Set condition) now operate on the leading or trailing edge of the input pulse?

____________.

Do the green LEDs (Reset condition) now operate on the leading or trailing edge of the input pulse?

____________.



* Resistors installed on ETB-6201-A only.

Figure 21-1

Summary

In step 3 L404 and L405 should be lit. This indicates that U401 is in the reset state. If LEDs other than L404 and L405 were lit, cycling the B logic switch would have turned them off.

Step 5 did not affect the circuit since data switch 1 is the K input and the flip-flop is already in the reset state.

In step 6, data switch 2 sets the J input high and when the A logic switch is cycled the flip-flop toggles to the set condition. When you cycle the A switch several more times the stages set and no other changes occur.

You should have noticed that the A logic switch caused the LEDs to react to the trailing edge of the pulse. The green LEDs all reacted at the same time to the leading edge of the B logic pulse. You should have seen that the green and red LEDs are compliments of each other.

When you set SW400 positions 4 and 5 on, both U401 and U402 were activated and four of the eight LEDs around U401 were lit and four were out. When you cycled the B logic switch all four green LEDs lit.

In step 13 through 18, the A logic switch had no effect on the circuit. Because the flip-flops are already reset, the B logic switch had no effect on the circuit.

In step 19 with J high and K low the A logic switch caused the flip-flops to set. Once set (L408-L411 lit) the A logic switch had no effect on the circuit. With J and K both high, only one section of each flip-flop will set. This illustrates the master-slave operation of the JK flip-flop.

In step 25 with all stages set and K high and J low, the A logic switch caused the flip-flops to reset. Once reset, the A logic switch has no effect on the circuit.

In step 30 with K high and J low, the A logic switch programs (loads) zeros into the flip-flop. With J high and K low, the A logic switch programs ones into the flip-flops. The B logic switch clears all of the flip-flops to the reset (zero) condition.

Again in step 33 the LEDs respond to the trailing edge of the A logic pulse and the leading edge of the B logic switch. When the jumper is moved from TP910 to TP909 both the A and B logic switches cause the flip-flops to trigger on the leading edge. In both cases, the LEDs respond to a high to low pulse change.

The A logic terminal (TP910) is low and when switched goes high and returns low. The B (NOT) terminal (TP907) is high and when switched goes low and returns to a high.

The JK flip-flop is a programmable binary device that contains two bistable circuits. JK flip-flops can be cascaded to extend storage capability.

Experiment 22
The 7495 Chip

Purpose

To demonstrate another circuit that stores binary bits.

To demonstrate data routing.

To demonstrate loading a shift register.

To demonstrate the shift operation.

Introduction

In this experiment, you will program binary inputs of zero and one into a 7495 4-bit binary register.

By cascading 7495 chips, you can store as many binary bits as there are bistable devices in your circuit.

When using the push button and logic slide switches for input pulses, be alert for switch bounce. Switch bounce is defined as more than one output for a switch cycle. Switch bounce can be reduced or eliminated by applying a constant pressure to the switches.

Procedure

1. Connect jumper wires as listed below.

PINS ON 7495	TO	FUNCTION
1 (TP516)		GROUND (ETB-6201 use main trainer) (ETB-6201-A use GND pin block 9)
2 (TP520)		DATA SW 1 (TP914)
3 (TP517)		DATA SW 2 (TP913)
4 (TP521)		DATA SW 3 (TP912)
5 (TP518)		DATA SW 4 (TP911)
6 (TP522)		B (TP908)
8 (TP515)		SW900 (TP900)
10 (TP514)		L4 (TP905)
11 (TP513)		L3 (TP904)
12 (TP512)		L2 (TP903)
13 (TP511)		L1 (TP902)

Make sure all data switches are switched low.

2. Set the 8-position dip switch in block 4 (SW400) to 6 and 7 up. Turn the trainer on and observe the LEDs on the main trainer.

3. Are any of the LEDs on the main trainer (L1, L2, L3, or L4) lit?

__________.

If any of the LEDs are lit, hold the B logic switch down and press SW900. Release the switches. Now, what is the condition of the LEDs?

__________.

4. Set all of the data switches to their high (up) positions.

Hold the B logic switch low and press and release SW900. Release the B logic slide switch.

What is the condition of the LEDs at this time?

________________.

Press and release SW900 four times.

Which direction did the data move?

________________.

5. Set data switches 2 and 3 high and data switches 1 and 4 low.

While watching the LEDs, hold the B logic slide switch down and press and release SW900.

Which LEDs are now lit?

________________.

6. Press and release SW900 three times.

Which direction did the data shift?

________________.

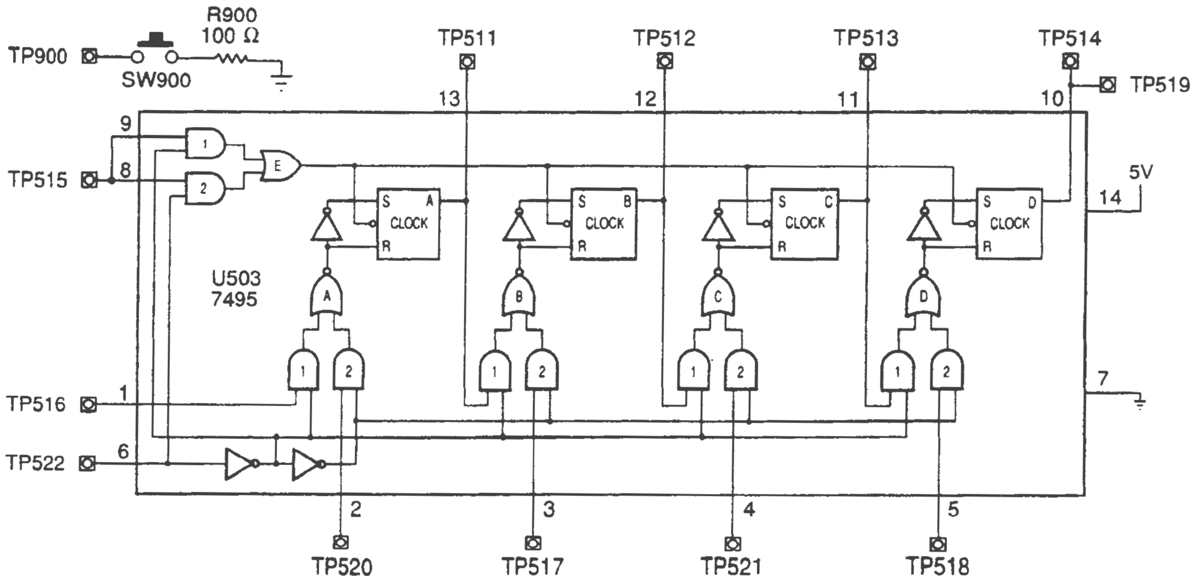


Figure 22-1

Summary

The 7495 in an MSI shift register. It combines RS flip-flops with basic logic gates to form a shift right register.

The data switches provide the highs and lows for the 4-bit binary coded data. When the data switches are up they provide highs. When the switches are down they provide lows. Usually the highs are selected to represent ones and the lows represent binary zeros.

By holding the B logic slide switch down and pressing and releasing SW900 you program the 4-bit register. The 4-bits are coupled (routed/programmed) into the register in parallel. Therefore, all four LEDs respond at the same time. In this configuration, the LED responding as the LSB or MSB must be specifically identified.

Then you released the B logic slide switch. Next, you used SW900 to accomplish the shift-right operation. When all four LEDs are lit and shifted right, it is not obvious if you are shifting the pulses out of the register to the right or simply turning off the LEDs from left to right.

By programming the binary data 0110 into the register and then shifting the data, it becomes obvious that the position of the lit LEDs shifted to the right each time you cycled the A logic push-button switch.

The data is loaded in parallel, but shifted serially. The shift pulse is applied to the left block of the register and all of the data moves right, one block for each input shift pulse.

You should have realized that in this type of register, when the data is shifted out there is no provision for recovering the data. Once the data is shifted out of the register in this configuration, it is lost.

Experiment 23
Left/Right Shift Register

Purpose

To demonstrate data routing.

To demonstrate loading a shift register.

To demonstrate the shift right/left operation.

Introduction

In this experiment, you will again program the binary inputs of zero and one into a 7495 4-bit binary register.

By changing the external wiring of the 7495 chip, you will be able to shift the data in either direction. This is especially important in the arithmetic unit of a digital computer. The arithmetic unit contains the registers that perform the mathematical manipulations on the binary data. A combination of registers make up the accumulator section of the arithmetic unit.

Procedure

1. Connect the jumper wires as listed below.

PINS ON 7495	TO	FUNCTION
1 (TP516)		DATA SW 1 (TP914)
*2 (TP520) to (TP512)		L2 (TP903)
*3 (TP517) to (TP513)		L3 (TP904)
*4 (TP521) to (TP514)		L4 (TP905)
5 (TP518)		DATA SW 4 (TP911)
6 (TP522)		DATA SW 2 (TP913)
8 (TP515)		SW900 (TP900)
13 (TP511)		L1 (TP902)

   * Where multiple connections are required on the ETB-6201, use the solderless terminal block on the main trainer for the common connections. The ETB-6201-A provides dual pins at common connection points—in this case, TP512, TP513, and TP514.

2. Make sure all data switches are switched low. Then, set the 8-position dip switch in block 4 (SW400) to 6 and 7 up.

3. Turn the trainer on and observe the LEDs on the main trainer.

   If any of the LEDs are lit, cycle SW900 until all four LEDs on the main trainer are off.

4. Set data switch 1 to its high (up) position. While observing the LEDs press and release SW900 four times.

   What is the condition of the LEDs at this time?

   ________________.

   Which direction did the data move?

   ________________.

5. Set data switch 1 low and data switch 4 high.

   While watching the LEDs press and release SW900 four times.

   Which direction did the data move?

   ________________.

6. Set data switch 1 high and data switch 4 low. Press and release SW900 once.

   Which LED is now lit?

   ________________.

7. Set data switch 1 low. Press and release SW900 as you watch the lighting sequence of the LEDs. Stop cycling the switch when L_4 lights.

   In this circuit configuration, is L_1 tied to the register's input or output?

   ________________.

8. Is the data being stepped through the register in series or parallel?

   ________________.

9. Set data switch 2 high. At this time, data switches 1 and 4 should be low. Press and release SW900 twice.

10. Which direction did the data move?

_______________.

11. Which LED is now considered to indicate the input stage of the register?

_______________.

12. Which LED is lit at this time?

_______________.

13. Set data switch 4 high and cycle SW900 once.

What happened to the data in the register?

____.

14. Set data switches 2 and 4 low. Press and release SW900 twice. Which direction is the data moved?

_______________.

15. What function does SW900 perform with the data switches in the positions listed in the following steps?

16. With data switch 1 high?

____.

17. With data switch 1 low?

____.

18. With data switch 2 high?

____.

19. With data switch 2 low?

____.

20. With data switch 4 high?

____.

21. With data switch 4 low?

____.

22. With data switches 1, 2, and 4 low?

____.

23. With data switches 1, 2, and 4 high?

____.

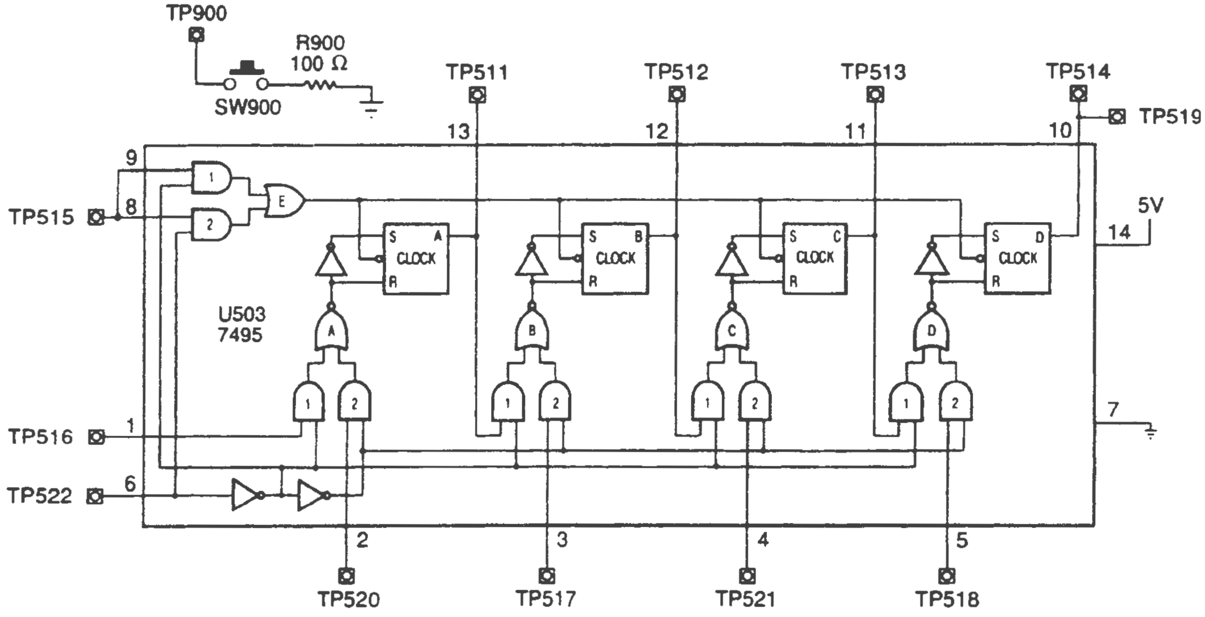


Figure 23-1

Summary

The 7495 is an MSI shift right/left register.

SW900 performs the load function.

Data switch 1 provides the highs and lows for the shift right operation. When data switch 1 is up, the data switch provides a high. When the switch is down it provides a low. In this case, the highs are selected to represent binary ones and the lows represent binary zeros.

Data switch 4 provides the highs and lows for the shift left operation.

Data switch 2 controls the direction of data movement in this shift register. When data switch 2 is low, the register is a shift right register. When data switch 2 is high, the register is a shift left register.

When all three data switches are low **no** data is loaded into the register and you can't be sure what is happening inside the register unless you first load ones into the register. However, it does perform the shift right function.

When all three data switches are high, it is a shift left register and after four shift pulses all of the LEDs are lit.

In a shift right register, L_1 is considered to be tied to the input. In a shift left register, L_4 is considered to be tied to the input.

In both the shift right and shift left configuration, the data is loaded and moved serially. This is indicated by the sequential lighting of the LEDs.

You should have realized that in this type register, when the data is shifted out, there is no provision for recovering the data. Once the data is shifted out of the register it is lost.

This register uses the LEDs positional weight to represent numerical values. When the data is shifted left, the number is doubled. This is one method of multiplying by a power of two.

When the data is shifted right, the numerical value is halved. This is the same as dividing by a power of two.

The disadvantage of using this register for multiplication and division is that there is no provision for the carry and borrow functions. By adding additional circuitry this problem can be overcome.

Experiment 24
Recirculating Shift Register

Purpose

To demonstrate data routing.

To demonstrate loading a shift register.

Introduction

In this experiment, you will again program the binary inputs of zero and one into a 7495 4-bit binary register.

By changing the external wiring of the 7495 chip, you will be able to save the data as you shift it out of the register. This overcomes that disadvantage which you observed in the last two experiments.

This is especially useful in memory storage operations and when performing arithmetic functions. In these types of applications, you will want to retrieve the data from memory, use the data, and store the results and original data back into memory.

Procedure

1. Connect the jumper wires as listed below.

PINS ON 7495	TO	FUNCTION
*1 (TP516)	to (TP514)	L4 (TP905)
2 (TP520)		DATA SW 4 (TP911)
*3 (TP517)	to (TP511)	L1 (TP902)
*4 (TP521)	to (TP512)	L2 (TP903)
*5 (TP518)	to (TP513)	L3 (TP904)
6 (TP522)		DATA SW 1 (TP914)
8 (TP515)		A (TP910)

* Where multiple connections are required on the ETB-6201, use the solderless terminal block on the main trainer for the common connections. The ETB-6201-A provides dual pins at common connection points—in this case, TP511, TP512, TP513, and TP514.

2. Make sure all data switches are switched low. Then, set the 8-position dip switch in block 4 (SW400) to 6 and 7 up.

3. Set data switches 1 and 4 up (on). Turn the trainer on, the LEDs may light in a random fashion.

   Press and release logic switch A four times while observing the LEDs on the main trainer. Use constant pressure to prevent switch bounce .

4. What is the condition of the LEDs at this time?

   ______________.

5. Turn data switch 4 off. Press and release the A logic switch three times.

   What function is now being performed?

   ______________.

6. Turn data switch 1 off and data switch 4 on.

   Press and release the A logic switch three times.

   What did you notice about the register's operation?

   ______________________________.

7. Turn data switches 1 and 4 on. Press and release the A logic switch two times.

   Which LEDs are now lit?

   ______________.

8. Turn data switch 1 off. Press and release the A logic switch four times.

   Which LEDs are now lit?

   ______________.

   Which direction did the data move?

   ______________.

9. Is the data being stepped through the register in series or parallel?

   ______________.

10. Which LED is now considered to indicate the input of the register?

    ______________.

11. What function does the A logic switch perform?

    ______________.

12. What function is performed with data switch 1 high and data switch 4 low?

    ______________.

13. What function is performed with data switch 1 high and data switch 4 high?

_________________ .

14. What function is performed with data switch 4 high and data switch 1 low?

_________________ .

15. What function is performed with data switch 4 low and data switch 1 low?

_________________ .

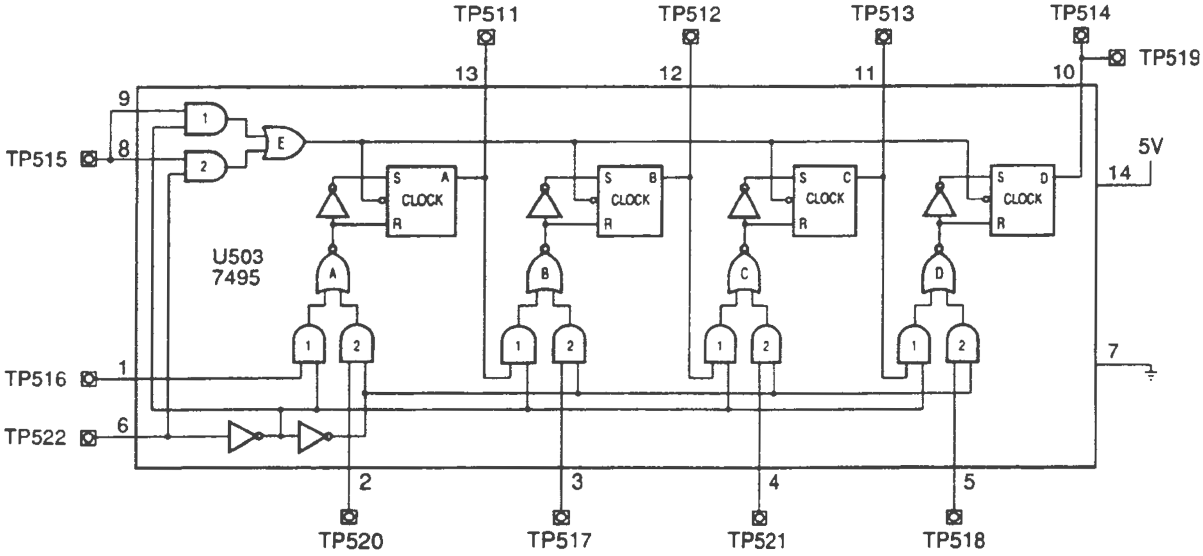


Figure 24-1

Summary

The A logic switch performs the load/shift function.

Data switch 4 provides the highs and lows for the binary data. When the data switches are both up, you are ready to program ones into the register. To program the data, cycle the A logic switch for every 1 desired. To program a 0, set data switch 4 low and cycle the A logic switch for every 0 desired.

With data switch 1 low and data switch 4 high, the register becomes a shift right recirculating register.

With data switch 1 high and data switch 4 low, the register is a shift right register and the data is shifted out of the register and lost.

In a shift right register, L_1 is considered to be tied to the input stage. The data in this circuit configuration is serially loaded and moved. This is indicated by the lighting of the LEDs in the sequence L_1, L_2, L_3, and L_4.

The A logic switch moves the data.

To program ones, data switches 1 and 4 should be high.

To program a zero, leave data switch 1 high and set data switch 4 low.

To shift right, data switch 1 should be high. If data switch 4 is high the register is filled with ones. If data switch 4 is low the register is cleared to zero.

In this configuration, with data switch 1 low, the register becomes a recirculating shift right register with data switch 4 either high or low.

Experiment 25
The Johnson Ring Counter

Purpose

To demonstrate data routing.

To demonstrate a special type of ring counter.

Introduction

In this experiment, you will again use a 7495 4-bit binary serial register.

By changing the external wiring of the 7495 chip, you will convert the recirculating register into a Johnson (switch tail) register.

As you know, in a standard ring counter the location of a lit led has a positional weight. Usually, only one LED is lit at any given time in a ring counter. Therefore, to represent values in the decimal number system, using a ring counter requires ten flip-flops and ten LEDs (0—9).

The Johnson switch tail ring counter can represent ten values using only 5 flip-flops. In this example, we will display eight different values using four flip-flops.

Procedure

1. Connect jumper wires as listed below.

PINS ON 7495	TO	FUNCTION
1 (TP516)		Pin 8 of U102 (TP110)
10 (TP519)		Pin 9 of U102 (TP109)
6 (TP522)		GROUND (ETB-6201 use main trainer) (ETB-6201-A use GND pin block 9)
8 (TP515)		SW900 (TP900)
10 (TP514)		L1 (TP902)
11 (TP513)		L2 (TP903)
12 (TP512)		L3 (TP904)
13 (TP511)		L4 (TP905)

Make sure all data switches are switched low.

2. Set the 8-position dip switch in block 4 (SW400) to 6 and 7 up, and SW100 in block 1 to 5 up. Turn the trainer on and observe the LEDs on the main trainer.

3. Are any of the LEDs on the main trainer (L1, L2, L3, or L4) lit? Record which ones are lit in the first line of the truth table on the next page.

INPUTS				OUTPUTS			
A	B	C	D	L1	L2	L3	L4
0	0	0	0				
0	0	0	1				
0	0	1	0				
0	0	1	1				
0	1	0	0				
0	1	0	1				
0	1	1	0				
0	1	1	1				

Figure 25-1

4. Press and release SW900.

   Plot the position of the lit LEDs in the second line of the table.

5. Cycle SW900 six more times and record the LED status in the remaining six lines of the truth table. Take time to examine the data to see if the lit LEDs correspond to a number system (either binary, octal, BCD, or HEX).

6. After examining the contents of the truth table, move the jumper wire from switch SW900 (TP900) to the C (clock) terminal (TP906). Make sure the clock is set to the 1Hz position on the Trainer.

   Watch the LEDs until they are all out. As soon as they are out, compare the next lit LED's position to the position that you plotted in row 1. Continue your comparison through all eight changes.

7. Do the lit LEDs represent one of the common weighted computer codes?

______________.

8. Did the automatic clock input agree with the data you manually clocked into the register?

______________.

9. What function does SW900 perform?

____.

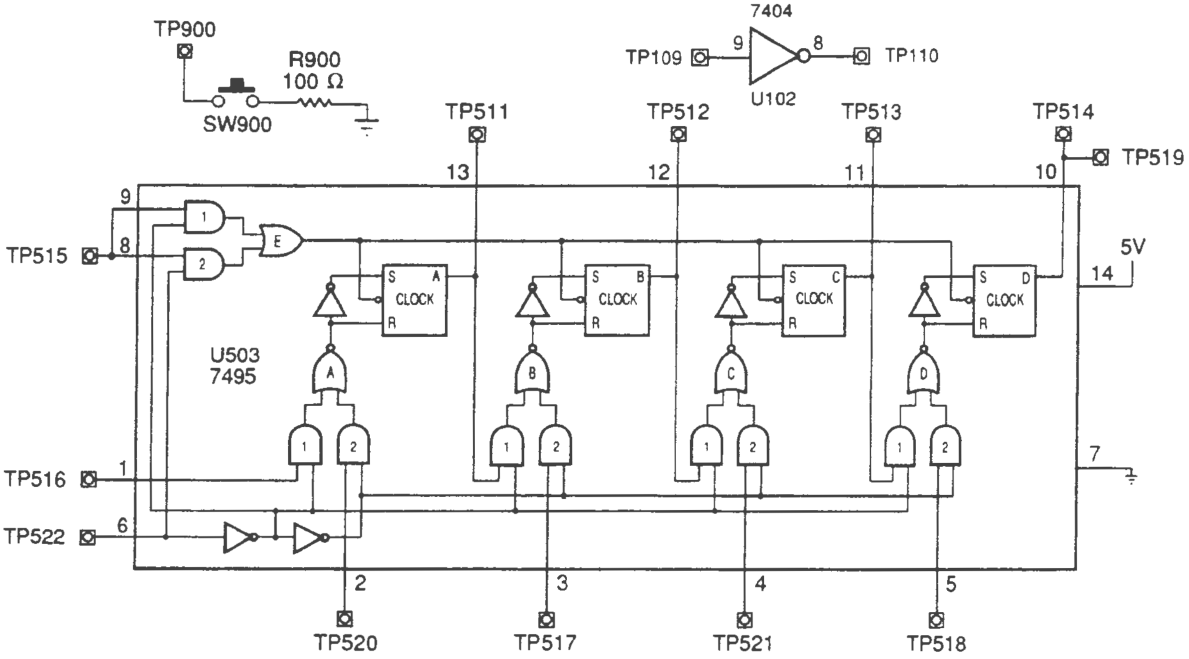


Figure 25-2

Summary

This circuit configuration is a switch tail Johnson counter, where each LED is used twice. It first sequences through the counter right-to-left, loading the counter with all ones. Then, it shifts the bits out of the counter, from right-to-left.

For example, one input pulse is represented by only L4 being lit. Seven more inputs result in only L1 being lit.

Remember that a standard ring counter requires as many blocks (flip-flops) as there are digits to be stored. The value of the stored data is indicated by **positional notation** and is not a binary value.

SW900 performs both the load and the shift function.

To program the data, cycle SW900 for every step in the truth table.

The data in this configuration is still serially loaded and moved. This is indicated by the lighting of the LEDs in the sequence L4, L3, L2, and L1.

The Johnson ring counter is a sequence register in that it provides a different visual response for each of the eight input pulses applied. The LED code for two input pulses is 0011. The response for seven input pulses is 1100. As you can see, this is not the binary weighted code (8, 4, 2, 1), and it does not represent a decimal value. It is simply a technique of distinguishing the eight changes that occur.

Experiment 26

The 7476 Up Counter

Purpose

To demonstrate storing binary bits.

To demonstrate data routing.

To demonstrate the counting base of number systems.

Introduction

In this experiment, you will use a pair of 7476 dual JK flip-flops.

By changing the external wiring of the 7476 chip, you will cause the circuit configuration to display 4-bits. This circuit configuration is capable of displaying data in the binary code, hexadecimal code, octal code, or the BCD code.

This counter can be used to represent up to sixteen different values using four flip-flops (two 7476 dual JK flip-flops).

Procedure

1. Connect a jumper wire between TP504 and the B(NOT) terminal (TP907).

   Connect a jumper wire between TP500 and TP505.

   Connect a jumper wire between TP501 and data switch 1 (TP914).

   Connect a jumper wire between TP110 and TP506.

   Connect a jumper wire between TP109 and the clock (TP906).

2. Set SW500 to 2, 6, 7, and 8 up. Set data switch 1 to the up (on) position. Set SW 100 to 5 up.

3. Turn the trainer on. Press and release the B logic slide switch and observe the operation of the LEDs in block 5.

4. What number code is represented by one LED?

   ____________________.

5. What is the radix of the number system displayed by the LEDs?

   ____________________.

6. Which LED indicates the LSB?

   ____________________.

7. Which LED indicates the MSB?

   ____________________.

8. Cycle the B logic switch.

   What is the function of the B logic switch?

   ____________________.

9. What is the function of the red LEDs?

_______________.

10. What is the function of the green LEDs?

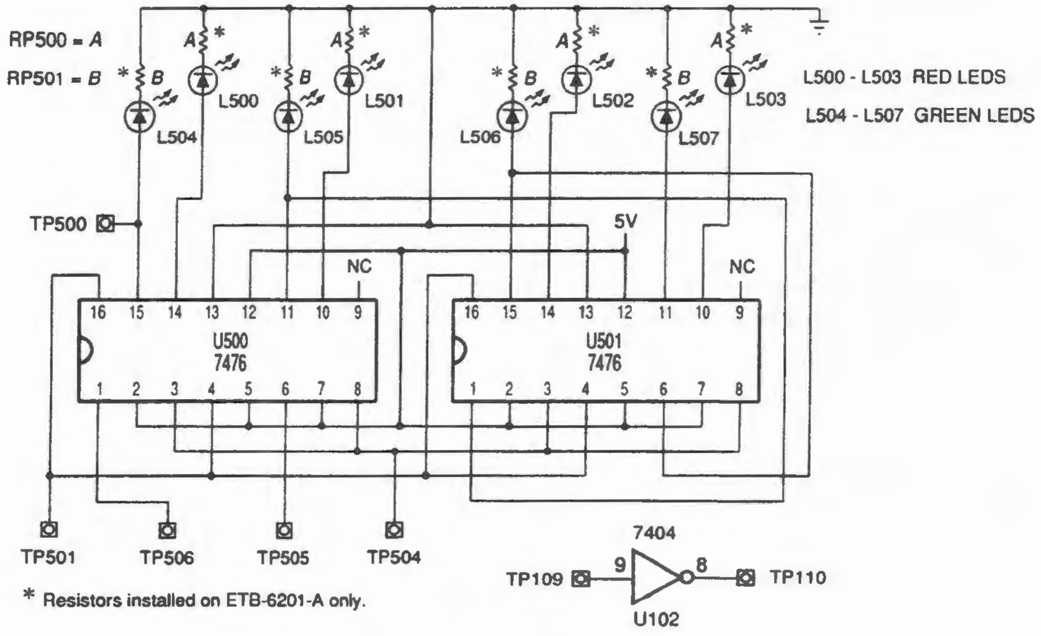
_______________.

11. How many input pulses does it take to fully load the counter?

_______________.

12. Set data switch 1 low.

13. What effect did this have on the circuit? _________________________
____.



* Resistors installed on ETB-6201-A only.

Figure 26-1

Summary

The 7476 in this configuration is a binary up counter. Since it displays 4-bits it can hold a maximum count of 1111. This is the equivalent of a decimal 15. The 1111 code could also represent an F in the hexidecimal code. Four binary bits are required to represent a digit (character) in a number system with a radix (base) of 16.

A single LED represents the binary code (base two number system). It can represent either a zero or a one.

L504 responds to each input pulse and is the LSB (least significant bit). L507 responds to the eighth input pulse and represents the MSB (most significant bit).

Remember, that a standard ring counter requires as many blocks (flip-flops) as there are digits to be stored. The value of the stored data is by positional notation and it is a binary function.

This circuit configuration can be considered to be a 4-bit binary counter with four separate digits or a hexidecimal code representing a single digit.

Notice that in this experiment, the red LEDs represent the compliment outputs and when lit indicate that the counter is storing zeros. The green LEDs represent the outputs and when lit indicate that the counter is storing ones. We switched from the normal mode of data representation to show you that it's not the color that signifies logic levels, but how you assign the colors to represent logic levels.

When data switch 1 is high, the counter responds to the input pulses applied to the toggle input. This happens because both J and K are tied high. When data switch 1 is low, the counter locks up and will not respond to the input pulses. This is because the J and K inputs are now tied low.

The data in this configuration is still serially loaded and moved. This is indicated by the lighting of the LEDs in the sequence L504, L505, L506, and L507.

The inverter from block 1 is used to condition the input signal before it is applied to the IC chip.

Experiment 27
Number Codes

Purpose

To demonstrate weighted codes.

To demonstrate data routing.

To demonstrate short counting.

Introduction

In this experiment, you will again use a pair of 7476 dual JK flip-flops.

By changing the external wiring of the 7476 chips, you will cause the circuit configuration to display 4-bits. This circuit configuration is capable of displaying data in the binary code, hexadecimal code, octal code, or the BCD code.

This counter can be used to represent up to sixteen different values using four flip-flops (two 7476 dual JK flip-flops).

Procedure

1. Connect a jumper wire between TP504 and the B(NOT) terminal (TP907).

   Connect a jumper wire between TP501 and data switch 1 (TP914).

   Connect a jumper wire between TP109 and C (clock) (TP906).

   Connect a jumper wire between TP500 and TP505.

   Connect a jumper wire between TP506 and TP110.

2. If you are using the ETB-6201 board, set SW500 to 2, 3, 4, 6, 7, and 8 up. If you are using the ETB-6201-A board, set SW500 to 1, 2, 4, 6, 7, and 8 up. Because of timing considerations, the two counting circuits are not identical. They differ in the position of switch SW500 1 in the circuit. See the schematic in Figure 27-1.

   Set Data switch 1 to the up (on) position. Set SW100 to 5 on.

   Turn the trainer on. Cycle the B logic slide switch and observe the operation of the LEDs in block 5.

3. What number code is now represented by the active LEDs?

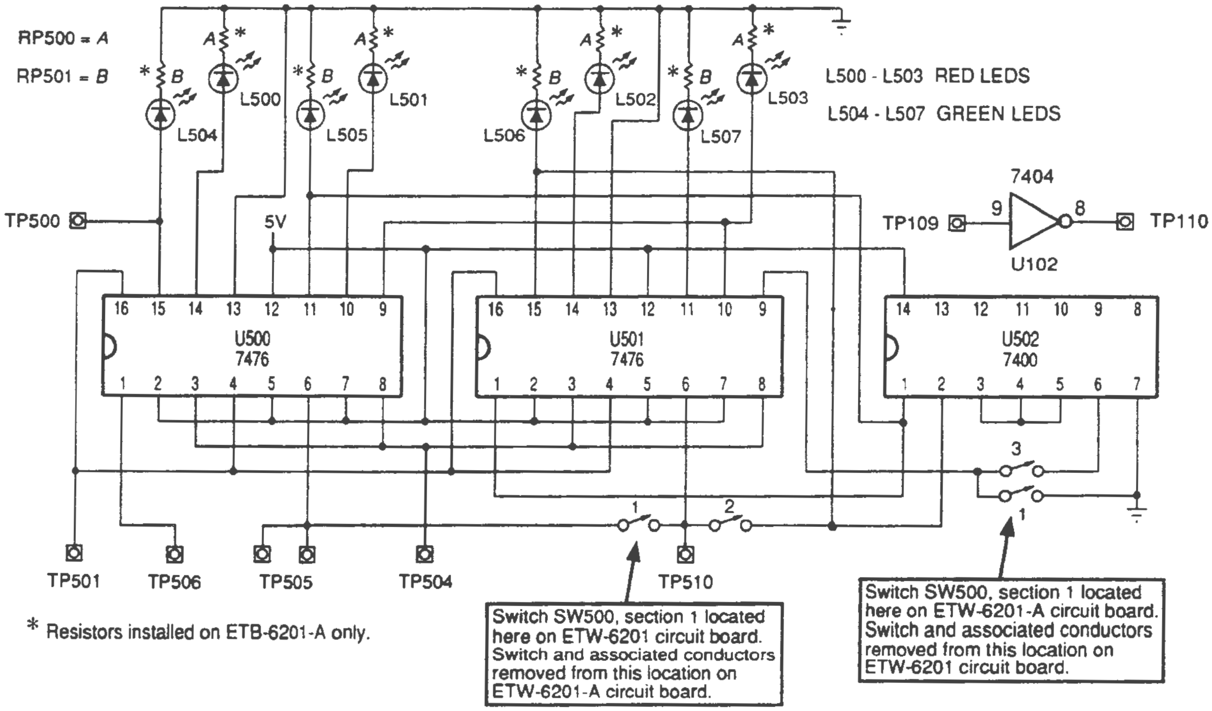
   ______________________.

4. Which LED indicates the LSB?

   ______________________.

5. Which LED indicates the MSB?

   ______________________.



* Resistors installed on ETB-6201-A only.

Switch SW500, section 1 located here on ETW-6201 circuit board. Switch and associated conductors removed from this location on ETW-6201-A circuit board.

Switch SW500, section 1 located here on ETW-6201-A circuit board. Switch and associated conductors removed from this location on ETW-6201 circuit board.

Figure 27-1

6. Cycle logic switch B. What is the function of the B logic switch?

   ____.

7. Set data switch 1 low. What effect does this have on the circuit?

   ____.

   Why?

   ____.

8. How many input pulses does it take to fully load the counter?

   ________________.

9. Describe the type of counter indicated by the operating LEDs.

   ____.

10. Set Data switch 1 high. Cycle the B logic switch and observe the automatic operation of the LEDs until you are sure of the counter's sequence of operation.

11. On the ETB-6201 board, set SW500 to 2 off and 1, 3, 4, 6, 7, and 8 on. On the ETB-6201-A board, set SW500 to 1 and 2 off and 3, 4, 6, 7, and 8 on, then connect the other TP505 to TP510.

    Cycle the B logic switch and observe the operation of the LEDs.

12. Now what is the largest digit represented by the green LEDs?

    ________________.

13. Now what is the counting base of the counter?

    ________________.

14. Explain the term short counting.

    ____.

15. What is the name of this weighted code?

    ________________.

Summary

The 7476 in this configuration is a 4-bit binary counter. However, it now displays only 3 bits. L503 remains lit (reset condition) and L507 never lights. The maximum count in this configuration is 111. This is the equivalent of a decimal 7.

The 111 code also represents 7 in the octal code. Notice that all 3 bits are required to register the largest digit that occurs in the base 8 (octal) number system.

In the prior experment, all four binary bits are required to represent the largest digit (character) in a number system with a radix (base) of 16.

In this configuration, the last flip-flop is not used. The counter has been shortened by one bit. However, all of the number combinations from 000 through 111 are used to describe the base eight number system.

Notice also, that the 3-bit binary, 4-bit binary, base eight (octal), and base sixteen (hexidecimal) counters are all power functions of 2.

In step 13, you changed the circuit configuration by changing the positions of the dip switches. This new configuration uses all four of the bits, but it does not use the full capability of all four bits. This is called short counting the counter.

The circuit configuration now uses the 8, 4, 2, 1 weighted code. However, the largest number displayed is represented by 1001. This is the equivalent of decimal 9. This configuration is capable of registering counts from 0000 through 1001.

Since there are ten distinct characters, the number system is base ten. When binary bits are used to represent digits in the base ten number system, it is called the BCD (binary coded decimal) code. The number codes from 1010 through 1111 are invalid codes in the BCD system and are not displayed by the LEDs. Instead 1010 causes the counter to reset and the count sequence is restarted.

The counter in this experiment is a count up serial counter. Logic switch B resets the counter to all zeros (red LEDs lit). The counter is then incremented to its full count capability (green LEDs lit). The next input pulse causes the counter to overflow. The overflow shifts all of the ones out of the counter and results in the reset condition.

Experiment 28
The 7476 Down Counter

Purpose

To demonstrate a binary down counter.

Introduction

In this experiment, you will again use a pair of 7476 dual JK flip-flops.

By changing the external wiring of the 7476 chip, you will cause the circuit configuration to display 4 bits. This circuit configuration could be used for displaying data in the binary code, hexadecimal code, octal code, or the BCD code as you saw in earlier experiments.

In this experiment, you will change the counter from a binary up counter to a binary down counter.

This counter can be used to represent up to sixteen different values using four flip-flops (two 7476 dual JK flip-flops).

Procedure

1. Connect a jumper wire between TP504 and the B(NOT) (TP907) terminal.

   Connect a jumper wire between TP501 and data switch 1 (TP914).

   Connect a jumper wire between TP109 and the clock (TP906).

   Connect a jumper wire between TP110 and TP506.

   Connect a jumper wire from TP502 to TP505.

   Connect a jumper wire from TP503 to TP508.

   Connect a jumper wire from TP509 to TP510.

2. Set SW500 to 6 and 7 up. Set SW100 to 5 up.

3. At this time, the 8-position dip switch (SW500) should have only positions 6 and 7 up (on).

   Set data switch 1 to the up (on) position. Turn the trainer on and observe the operation of the LEDs in block 5.

4. Cycle the B logic switch.

   What happens one count after you release the B logic switch?

   ____________________ .

   Which direction does the counter count?

   ____________________ .

5. When the counter is in the middle of its count sequence, set data switch 1 low (down).

   What happens to the count sequence with data switch 1 low?

   ____ .

6. Cycle the B logic switch.

   What happens to the stored data in the counter?

   ____ .

   Why?

   ____ .

7. Describe the type of counter indicated by the operation of the LEDs.

   ____ .

8. What is the counting base of this counter?

   __________.

9. Which LED represents the LSB?

   __________.

Summary

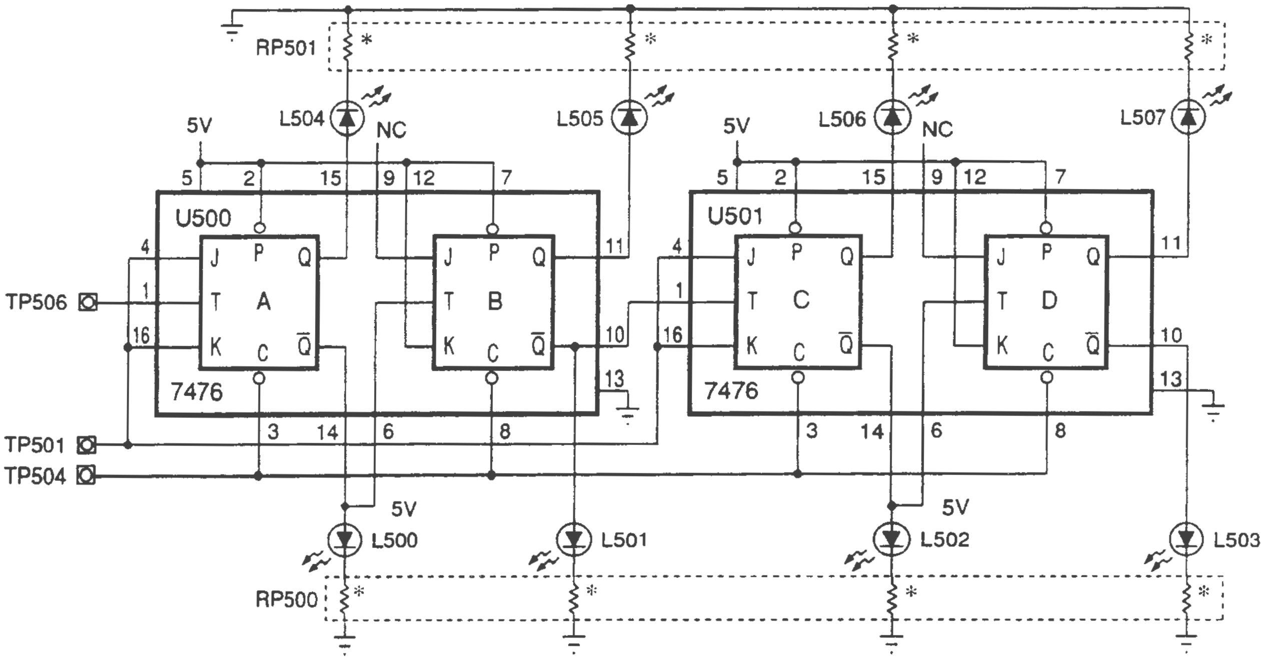
The 7476 in this configuration is still a 4-bit binary counter. However, it is now a down counter. The counter is cleared (reset) using the B logic switch, the next count pulse causes all four green LEDs to light. The counter continues to decrement until all of the green LEDs are out and all of the red LEDs are lit. The next input pulse causes all of the green LEDs to once again light and the count down sequence is repeated. This counter takes sixteen clock pulses for one complete cycle.

The red and green LEDs are compliments of each other. The green LEDs represent ones and the red LEDs represent zeros in the count down sequence. You should have noticed that as the green LEDs count down the red LEDs count up.

When Data switch 1 is set low, it locks the counter, retaining whatever data is presently stored. When Data switch 1 is returned high, the count down sequence continues. Data switch 1 controls the state of the J and K inputs of the flip-flops.

When the reset switch is cycled, the counter is cleared. This dumps the stored data, all of the green LEDs go out, and all of the red LEDs light to indicate that the counter is reset to zero.

The value of the stored data is by position and it is a binary function. In this counter the LSB is L504.



* Resistors installed on ETB-6201-A only.

Figure 28-2

Experiment 29
One-of-Four Decoder

Purpose

To demonstrate a binary decoder.

To demonstrate active high circuits.

To demonstrate active low circuits.

Introduction

In this experiment, you will use two ICs to make a 1-of-4 decoder circuit. The ETB-6201 circuit board uses 7404 and 7400 chips, while the ETB-6201-A uses 7442 and 7486 chips to provide the same 1-of-4 decoder output.

A decoder provides an output for a specific input combination. This is a form of multiplexer circuit. With two variable inputs there are four possible input combinations. Each of these inputs enables a different output.

In this circuit, you will also see what is meant by active high and active low circuits.

Procedure

1. In block 6, connect a jumper wire between TP600 and data switch 3 (TP912). Connect another jumper wire between TP601 and data switch 4 (TP911). Set data switches 3 and 4 to their low (off) positions. Set SW600 to 1, 2, 3, 4, 5, and 6 up (high). Turn the trainer on and observe the row of 4 LEDs in block 6.
2. Which LED indicates an input of 00?

_______________.

3. Set Data switch 4 high. Which LED indicates an input of 01?

______________.

4. Set Data switch 3 high and data switch 4 low. Which LED indicates an input of 10?

______________.

5. Set data switch 4 high. Which LED indicates an input of 11?

______________.

6. Assuming that a lit LED indicates a high, the output line (decoded output) is indicated as an active:

______________.
high/low

7. Set SW600 to 1, 2, 3, and 4 off (down), leave 5 and 6 up. Set data switches 3 and 4 low. At this time, SW600 should have only 5 and 6 up (on).

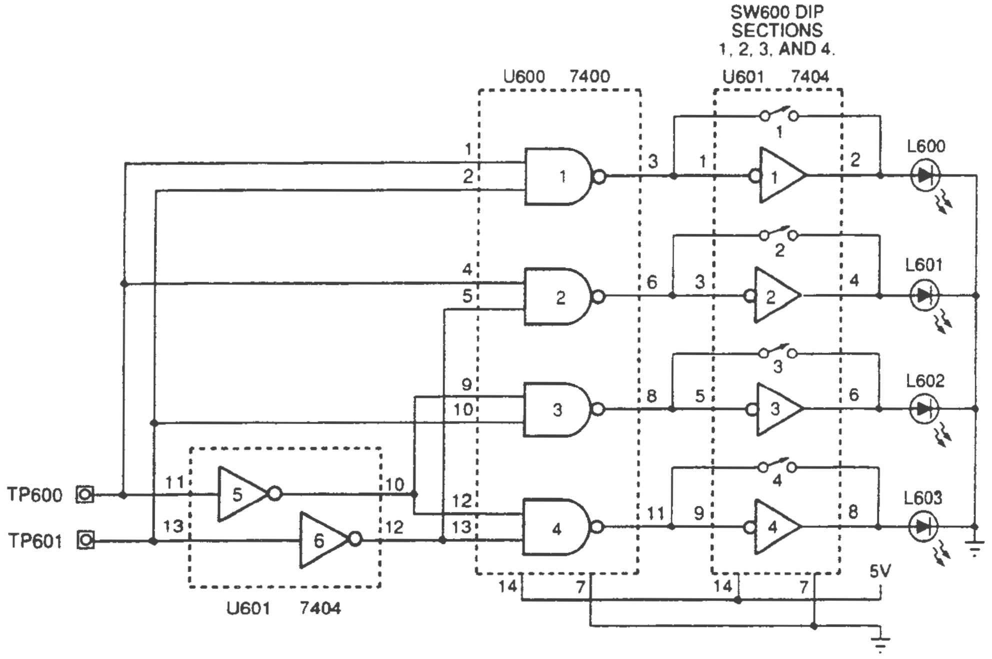


Figure 29-1A

ETB-6201 Circuit.

8. Which LED indicates an input of 00?

________.

9. Set data switch 4 high. Which LED indicates an input of 01?

________.

10. Set Data switch 3 high and data switch 4 low. Which LED indicates an input of 10?

________.

11. Set data switch 4 high. Which LED indicates an input of 11?

________.

12. Assuming that a lit LED indicates a high, the output line (decoded output) is indicated as an active:

________.
high/low

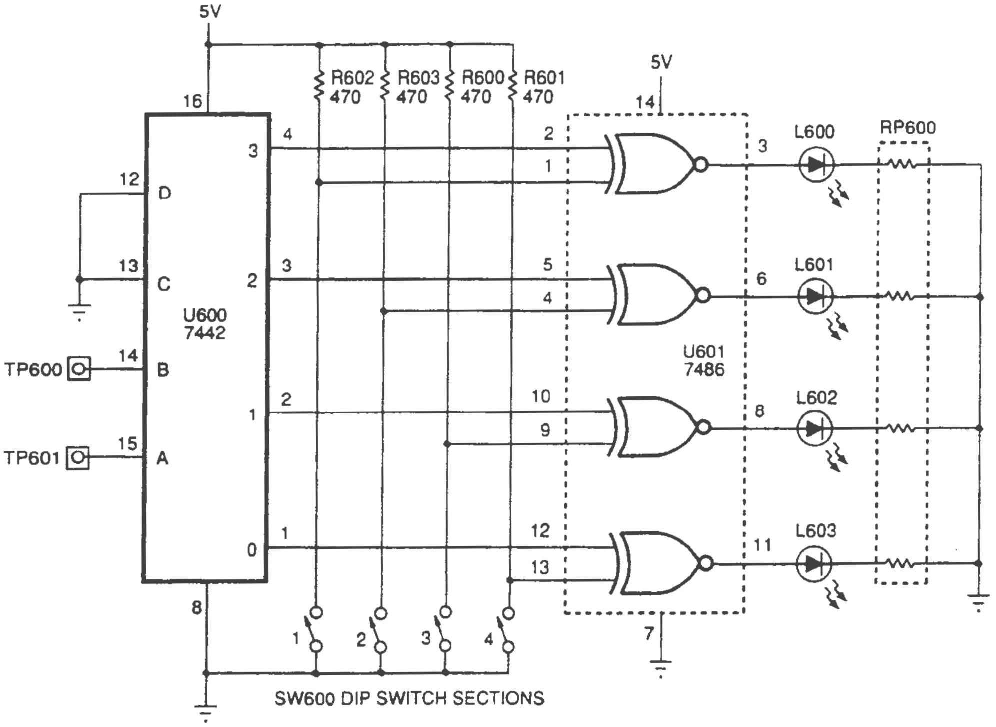


Figure 29-1B
ETB-6201-A circuit.

Summary

This configuration is a 1-of-4 decoder. It converts a two-input binary code into a decoded output. Each decoded output line is monitored by an LED.

When you sequence the switches through the four possible input combinations, one of the LEDs should indicate the decoded output.

In the first part of the experiment, only one LED is NOT lit for each input combination. As you changed the input code, the combination of lit LEDs changes, with the LED that is not lit is indicating the decoded output. This decoder is then said to be operating with an active low output. This could be considered negative logic.

When you set the first four positions on the dip switch low, three of the LEDs are out and only the decoded output line contains a lit LED. In this configuration, the circuit is active high. This is considered to be a positive logic circuit.

A multiplexer circuit takes many inputs and decodes them to enable a single output, or combination of outputs. As you can see this circuit has some multiplexing characteristics, in that it combines two inputs into a single output. The output can be selected either active high or active low, as demonstrated by the lighting sequence of the LEDs.

Experiment 30
The 7442 Chip

Purpose

To demonstrate a binary input decoder.

To demonstrate active low circuits.

To demonstrate illegal numerical codes.

Introduction

In this experiment you will use a 7442 decoder chip.

A decoder provides an output for a specific input combination. This is a form of multiplexer circuit. With four variable inputs there are sixteen possible binary input combinations.

Procedure

1. In block 6, connect a jumper wire between TP602 and data switch 4 (TP911).

   Connect a jumper wire between TP603 and data switch 3 (TP912).

   Connect a jumper wire between TP604 and data switch 2 (TP913).

   Connect a jumper wire between TP605 and data switch 1 (TP914).

   Set all four data switches to their low (off) positions.

   Set SW600 to 7 and 8 up (high).

   Turn the trainer on and observe the row of 10 LEDs in block 6 as you cycle through the sixteen possible input combinations. (Assume that data SW4 controls the LSB.)

   Record the active LED for each input combination.

INPUTS				OUTPUT
A	B	C	D	
0	0	0	0	
0	0	0	1	
0	0	1	0	
0	0	1	1	
0	1	0	0	
0	1	0	1	
0	1	1	0	
0	1	1	1	
1	0	0	0	
1	0	0	1	
1	0	1	0	
1	0	1	1	
1	1	0	0	
1	1	0	1	
1	1	1	0	
1	1	1	1	

Figure 30-1

2. Which LED indicates an input of 0000?

_______________.

3. Set Data switch 4 high. Which LED indicates an input of 0001?

_______________.

4. Set Data switch 3 high and data switch 4 low. Which LED indicates an input of 0010?

_______________.

5. Set data switch 4 high. Which LED indicates an input of 0011?

_______________.

6. Assuming that a lit LED indicates a high, the output line (decoded output) is indicated as an active:

_______________.
high/low

7. Continue programming the binary inputs into the decoder until you have completed all 16 combinations. Each time you increment the input, note the condition of the LEDs.

In which direction are the LEDs sequencing?

_______________.

8. Did all sixteen input combinations result in an LED changing states?

_______________.

If not, why not?

____ .

9. What type of decoder do your outputs indicate?

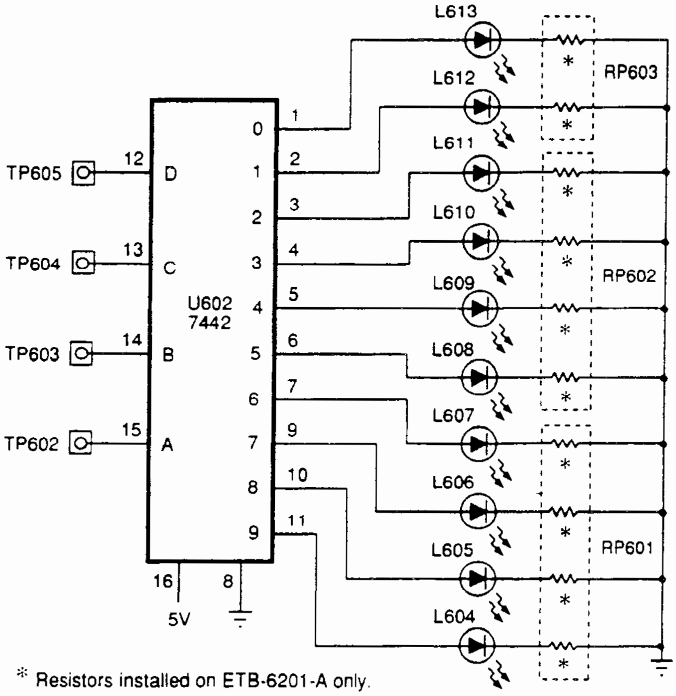
______________.

10. How many input combinations do not result in an LED change of state?

______________.

11. What are these input combinations called?

______________.



* Resistors installed on ETB-6201-A only.

Figure 30-2

Summary

This circuit configuration is a 1 of 10 active low decoder. It converts the four input binary code into ten decoded outputs. Each decoded output is routed out of the decoder on a separate data line. Each of the ten output lines is monitored by an LED.

When you sequence the data switches through the first ten possible input combinations, a different LED should indicate each decoded output. The active output line is referenced by the unlit LED.

For six of the input combinations (1010, 1011, 1100, 1101, 1110, and 1111) no LED changes states (they all remain lit). This indicates that for these six combinations no output is generated. In other words, this decoder does not respond to these inputs. These six codes are referred to as illegal states.

You should recall that in a BCD counter these same illegal states were available with 4 flip-flops, but the counter was short counted to prevent their being displayed. Thus, the 7442 is a BCD decoder when it has a four bit input code.

Since it only provides a single output at any given time, it is a positional decoder. In this example, the 7442 chip is used to indicate the ten characters in the decimal number system. The zero output is located at L613 and nine (1001) is L604.

This is very similar to the ring counter that has only one lit LED at any given time. The lit LED has a positional weight. In this decoder the active LED goes out, which indicates an active low output.

To have the LEDs light to indicate which output line is active, the LEDs would be preceeded by inverters as demonstrated in the 1 of 4 decoder in the last experiment.

The LEDs respond to ten of the inputs by indicating an output where the LED is not lit. This decoder has an active low output. Since the decoder provides ten separate outputs for the four inputs, it is considered to be a 1 of 10 (BCD) decoder.

Experiment 31
Decoder Driver Circuit

Purpose

To demonstrate a binary input decoder.

To demonstrate a BCD output decoder.

To demonstrate converting binary inputs to both BCD and decimal number codes.

To demonstrate the operation of a 7-segment display.

Introduction

In this experiment, you will use a 7490 and a 9368 chip. This combination is called a decoder driver. It will be used to drive a 7-segment display. As you have seen in earlier experiments, LEDs are used as visual display devices. In some cases, the LEDs simply indicate the presence or absence of a high.

In many of the earlier experiments, the LEDs were used to indicate a specific number code. To identify the number code, it is necessary to know what positional weight is assigned to each LED. It is also necessary for you to know if a binary 1 is indicated by an LED turning on or turning off.This is necessary for you to differentiate between active high and active low circuits. It is also one means of identifying if the circuit is using positive or negative logic.

As you will see, when a 7-segment display is used, it reads out in the number system with which you are the most familiar. This takes a lot of the guess work out of operator interpolation.

The computer is allowed to work in the number system that is most efficient. At the same time, the operator is allowed to program and monitor the computer's operation in the number system most efficient for him or her.

A decoder provides an output for a specific input combination. This is a form of a multiplexer circuit. With four variable inputs there are sixteen possible binary input combinations.

Procedure

1. In block 7 connect a jumper wire between TP700 and TP900.

   Connect a jumper wire between TP701 and the clock (TP906).

2. Set SW700 to all high.

3. Turn the trainer on and observe the LEDs and the 7-segment display.

4. What characters does the 7-segment display?

   ________________.

5. Press and hold SW900. Which LEDs are lit?

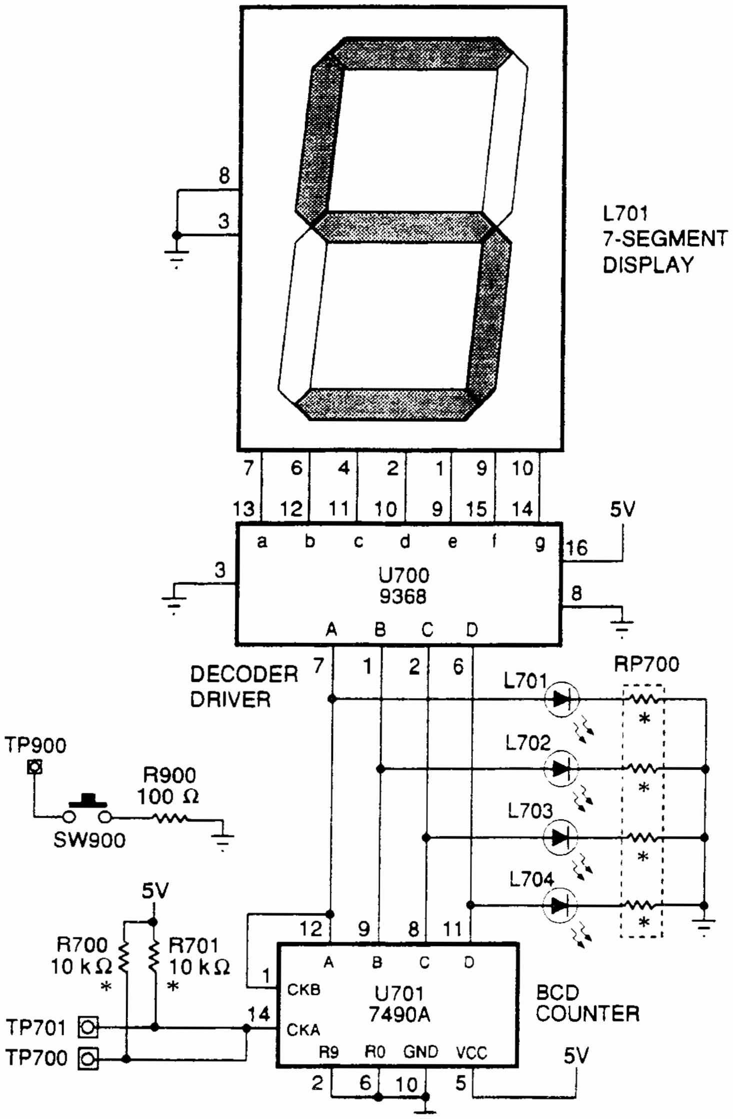
   ________________.

6. Which character does the 7-segment display?

   ________________.

7. Does the LED numerical code agree or disagree with the 7- segment display?

   ________________.



* Resistors installed on ETB-6201-A only.

Figure 31-1

8. While observing the LEDs and 7-segment display, release SW900.

9. Are the LEDs and 7-segment display tracking together?

   ________________.

   You can press and hold SW900 to stop the display for code verification.

10. What is the function of the 7490 chip?

    ________________.

11. What is the radix of the characters displayed?

    ________________.

12. Set SW700 to 1, 2, 4, 5, 6, 7, and 8 up.

    While observing the displays in block seven, press and release SW900 a few times.

    What effect did this have on your displays?

    ____ .

Summary

This circuit configuration is a BCD decoder driver. It converts the four input binary code from the 7490 BCD counter into a decimal output. The LEDs indicate the BCD code and the 7-segment display indicates the ten decimal characters.

The 9368 provides the drive current for the 7-segment display. It also decodes the four bit BCD input code into the seven outputs that are required to light all of the segments of the 7-segment LED chip.

Before deciding that the two displays are indicating the same number, you must establish the positional weight of the LEDs. Then the bits can be decoded into their decimal equivalent. In this circuit L704 is the MSB and L701 is the LSB.

This circuit configuration is an improvement on the 7442 because instead of being a positional indicator that is the equivalent of a decimal digit, it displays the real decimal character. This eliminates the confusion about which input position is the LSB.

In step 12, you converted the counter from a gated BCD counter into a manually operated counter. SW900 now becomes the manual programming switch.

Experiment 32
Memory Programming

Purpose

To demonstrate binary memory programming.

To demonstrate a hexadecimal output device.

To demonstrate converting binary inputs into hexadecimal characters.

To demonstrate the operation of a 7-segment display.

Introduction

In this experiment, you will use a 74193 to provide a 4-bit binary signal and a 9368 to decode the signal and drive a 7-segment display. As you have seen in earlier experiments, LEDs are used as visual display devices. In some cases, the LEDs simply indicate the presence or absence of a high.

In the last experiment, a binary code was decoded as BCD outputs and displayed in the 7-segment LED as a decimal character. This happens because the 7490 is a BCD counter.

The 4-bit output of the 74193 can represent 16 different values. All sixteen will be used to drive the 7-segment LED.

In addition to controlling the decoder driver, the 4-bit output of the 74193 is used to address a RAM IC. A 2114, 1K x 4 RAM is used on the ETB6201, while a 5188, 16K x 4 RAM is used on the ETB-6201-A. Both RAMs are used in the same manner, so the steps in this experiment are identical.

You will use the 74193 to address 16 different memory locations. Then you will modify the data within those locations, and generally, examine the operation of RAM.

Procedure

1. In block 8, connect a jumper wire between TP800 and TP900.

   Connect a jumper wire between TP801 and the B(NOT) logic slide switch (TP907).

   Set all SW800 switches to high. Set the four data switches low.

   Turn the trainer on and observe the LEDs and the 7-segment display.

2. If any of the LEDs are lit, or the 7-segment display shows something other than zero, cycle SW800 section 1 off and back on. If the 7-segment display is zero and any of the LEDs are lit, cycle the B logic switch.

3. While observing the 7-segment display and the LEDs in block 8, cycle SW900 to step the 7-segment display through its 16 address values.

4. Did any step have one or more LEDs lit?

   ______________.

5. If the answer to step 4 is yes, recycle through all sixteen of the memory steps. In each step where LEDs are lit, cycle the B logic switch. You may have to go through the steps more than once to reset all of the LEDs in all of the steps because of contact bounce in switch SW900.

6. Once all of the LEDs are out for all of the steps displayed, you know that you have stored binary zeros in those memory address locations. Reset the 8 position dip switch to 1, 2, 3, and 4 up, and 5, 6, 7, and 8 down.

CAUTION

IN THE FOLLOWING STEPS, **DO NOT** HAVE JUMPER WIRES CONNECTED BETWEEN THE RAM CHIP AND THE DATA SWITCHES WHEN POSITIONS 5, 6, 7, AND 8 OF THE DIP SWITCH ARE SET HIGH. THE LOAD ON THE INPUTS OF THE RAM MAY CAUSE INCORRECT DATA TO BE ENTERED.

7. Set all four data switches LOW.

   Connect a jumper wire between TP803 and data switch 1 (TP914).

   Connect a jumper wire between TP802 and data switch 2 (TP913).

   Connect a jumper wire between TP805 and data switch 3 (TP912).

   Connect a jumper wire between TP804 and data switch 4 (TP911).

8. Program the RAM chip as follows:

   a. Using SW900, step the 7-segment display until it displays 0.

   b. Cycle the B logic switch to program 0000 into the RAM chip.

   c. Cycle SW900 once. The display should change from 0 to 1.

   d. Program the data switches for a binary 1 (0001), and cycle the B logic switch.

   e. Cycle SW900. The display should change from 1 to 2.

   f. Program the data switches for a binary 2 (0010), and cycle the B logic switch.

   g. Continue to program the contents of the RAM chip to match the address value in the 7-segment display—remember, the display uses hexadecimal characters. This process sould be repeated 16 times to fully program the input combinations of a 4-bit data byte.

9. Once all sixteen combinations have been programmed, **disconnect** the jumper wires from the data switches.

   Set the 8 position dip switch (SW800) to **all** up.

   Set all of the data switches low.

10. Cycle SW900 until the 7-segment display indicates 0. At this time none of the LEDs should be lit.

11. Use SW900 to step the display through its 16 address locations while observing the LEDS. The data stored (indicated by the LEDs) should agree with the address shown by the 7-segment display.

    If one or more of your address locations do not contain the data you programmed, you can reprogram that address, or those addresses. Remember to switch sections 5, 6, 7, and 8 of dip switch SW800 **down** (off) **before** you reconnect the data switch jumper wires.

    Then, repeat the programming sequence stated in step 8 for each address that requires reprogramming.

    When finished with the reprogramming, **disconnect** the data switch jumpers, set SW800 to **all** up, and position the data switches low.

    Step through the memory locations using SW900 and compare the data that you reprogrammed to the value in the 7-segment display to ensure that the data is properly stored in memory.

12. Once you are satisfied that the data is correctly stored, turn the trainer off and wait a minute. Then, turn the trainer on and step through the stored memory using SW900.

13. Did the data remain properly stored?

    ______________.

    If not, why not?

    ____

    ____.

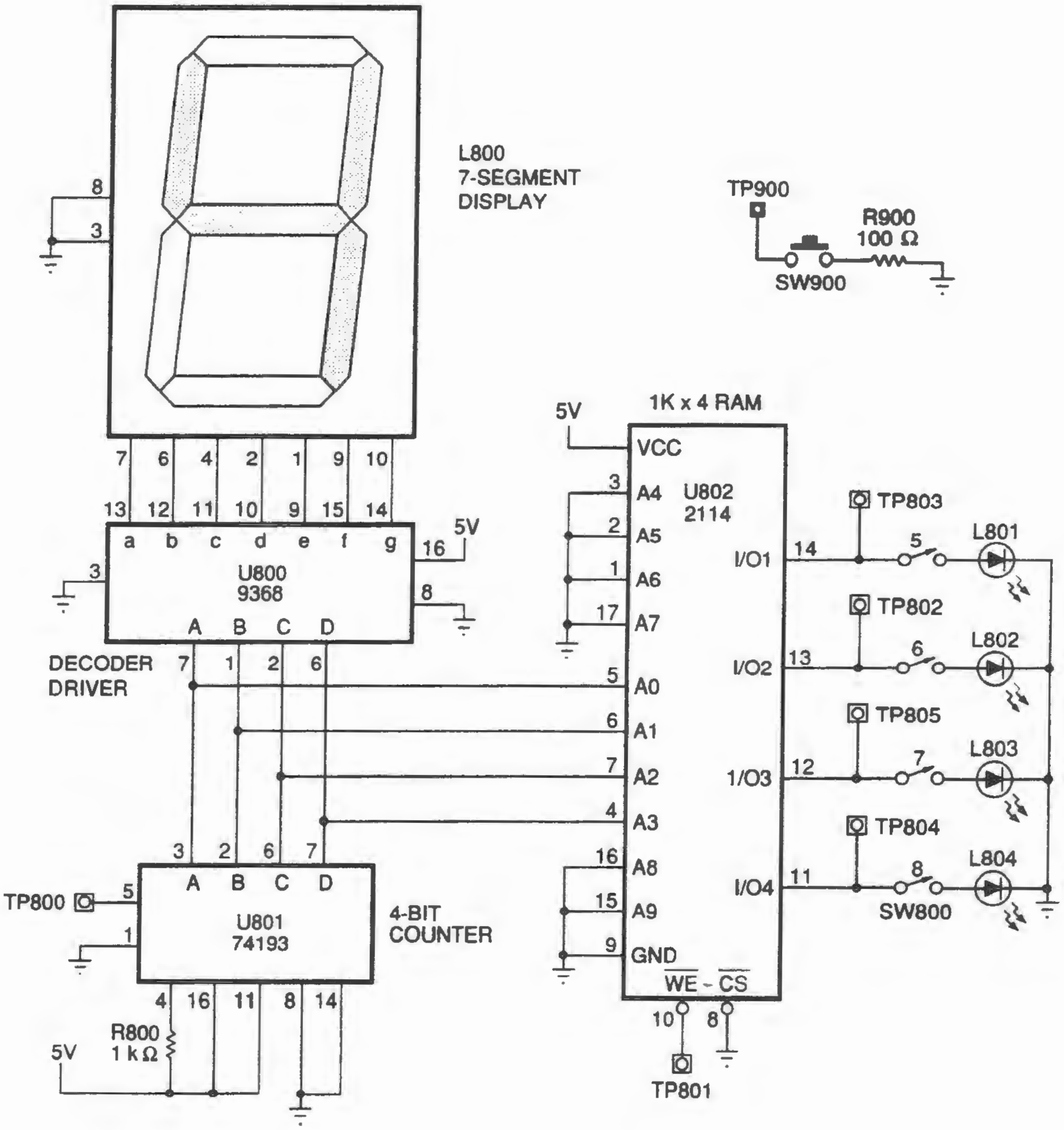


Figure 32-1A
ETB-6201 circuit board.

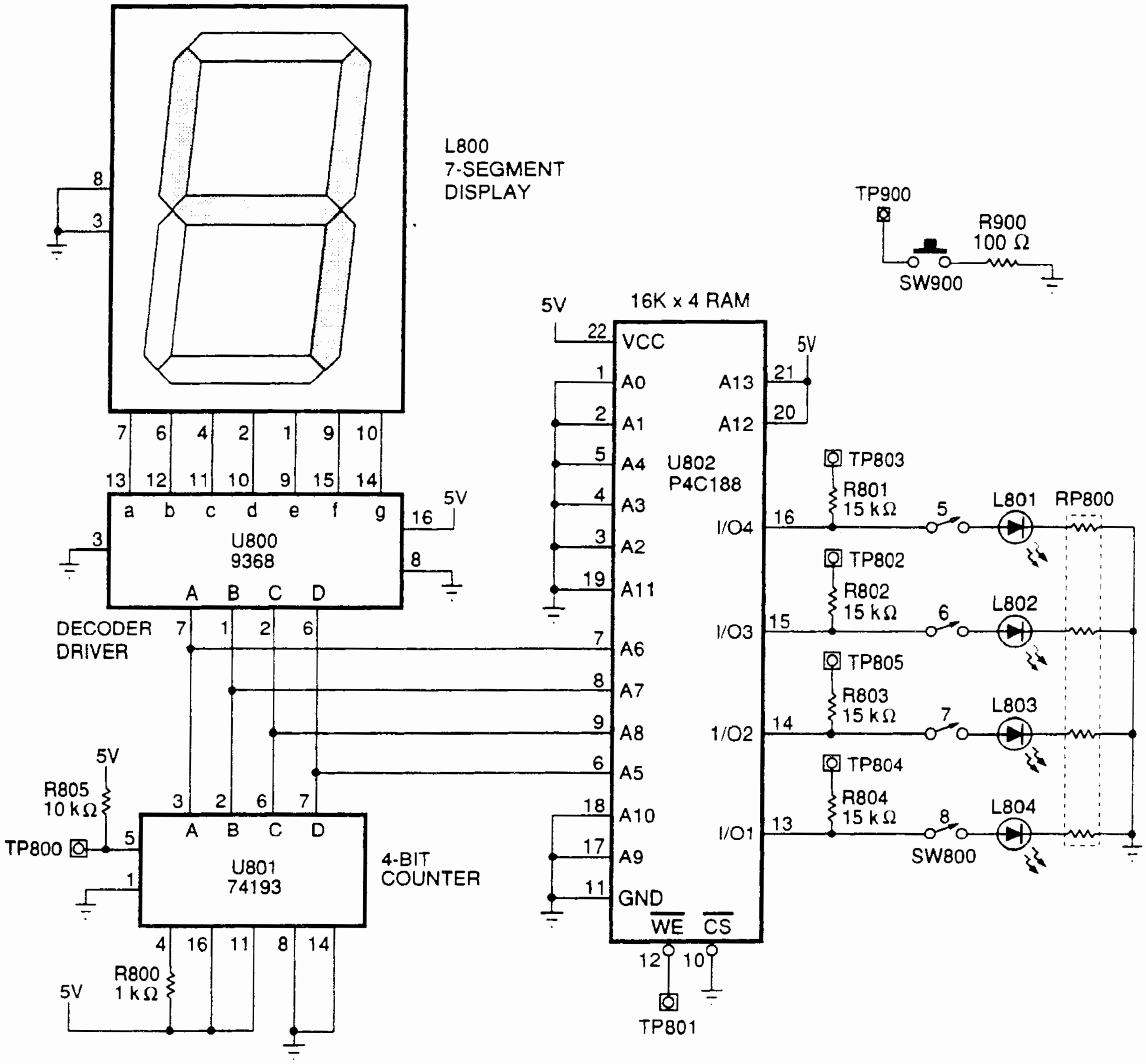


Figure 32-1B

ETB-6201-A circuit board.

Summary

This circuit configuration is a decoder driver that converts the 4-bit binary code from the 74193 binary counter into an output that can be displayed by the 7-segment display as hexadecimal characters. The four LEDs indicate the binary code.

In this circuit, the 74193 is called a binary counter and the 7-segment display is a hexadecimal readout.

The 9368 provides the drive current for the 7-segment display. It also decodes the four-bit input code into the seven outputs required to light all of the segments of the 7-segment display.

Before deciding that the four LEDs and the 7-segment display are indicating the same number, you must establish the positional weight of the LEDs. Then, the 4-bit bytes can be decoded into their hexadecimal equivalents.

The data in memory is lost, or randomized, when power is interrupted. That is because this type of memory is a volatile type. Most of the temporary memory devices used in computers are volatile. Long term memory data is usually stored in some form of media such as floppy disk, hard disk, tape, or some type of ROM.

Troubleshooting Experiments

The experiments in this section may or may NOT operate properly. To restore the circuits to their proper operation **WILL NOT** require you to use a soldering iron to repair the circuit board.

You may want to refer to the pinout diagrams and complete schematic blocks in Appendix A for the remaining experiments.

CAUTION

AS WITH ALL METERS, THE BACKPACK METER SWITCH MUST BE IN THE CORRECT POSITION TO PROPERLY OPERATE THE METER.

When using the Backpack AC meter function, remember that **only** the 200- and 500-volt ranges can be used.

When using the Backpack ohmmeter function, the trainer must remain on to power the meter circuit.

To disconnect power to the circuits on the board, place all of the DIP switches in all of the blocks in their off position. The board can also be slid up in the backpack board holder a short distance to isolate it from power, ground, and trainer signal lines. With all of the DIP switches off, the trainer's common ground can be used for the meter's reference. With the board isolated from the backpack signal connector, both ohmmeter leads must be connected across the circuit board foils or component leads when checking for continuity or some level of resistance.

Experiment 33
Sample Troubleshooting Problem

Purpose

To develop your skills in analyzing and testing digital circuits.

To reinforce your knowledge of digital circuits.

To familiarize you with some of the common types of problems associated with electronic circuits.

To provide practice in using test equipment.

Introduction

This practice troubleshooting experiment is provided to get you thinking along the same lines as the designer of the experiments that follow. You will examine a combinational circuit that contains a clock, hex inverter, and basic storage device.

In following the steps and explanations used in this experiment, remember that there are two distinctive types of electronic technicians. First is the assembly line technician who is responsible for the original testing, adjusting, and repair of new equipment. Second is the technician who is employed to repair equipment that once worked and has been returned for repair.

The assembly line technician can't be sure the equipment ever worked, that it is assembled correctly, or even that the proper parts were used in the assembly process. Most assembly work is performed by workers who are not trained in electronic technology.

Many assembly workers would not recognize a faulty procedure or an incorrect part. They simply follow a pictorial diagram and an established procedure to do their work. They usually work on a timed line and do the same repetitive task.

Like everyone else, they are subject to good and bad days. There is also the problem of last minute substitution of assembly workers during the assemble process. These last minute substitutes may or may not be fully trained in a specific job.

The assembly line technician's primary job is to find and eliminate errors in processes, procedures, or performance as early as possible. Once the products start coming off the line, a percentage will require only a minor alignment and functional test. Some of the units will be sidelined for repair because they failed one of the assembly line tests.

These units (the ones that didn't work) will be repaired by more experienced factory assembly technicians. The assembly technicians inspect for missing parts, wrong parts, parts installed backwards, solder bridges, no solders, lifted foils, and other common problems.

The first step in troubleshooting newly manufactured equipment is a visual inspection. This is where you want to detect any hazardous situations such as backward electrolytic capacitors, or high voltage shorts to ground. Both of which can cause injury to the technician and to the new equipment. An experienced inspector can see many of the human errors most common to a particular equipment. This inspector usually has a known good product with which to compare the new product.

Once the product has been reinspected, a full functional test is made to pin point the area or areas where problems exist. Next, the technician reviews a schematic to see if the problems are related. In other words, to see if the combined symptoms lead to a single cause of the problem. For example, all of the 5 volt circuits inoperative.

Next, the technician decides on a procedure to use for troubleshooting this particular problem. The following section contains some of the more common procedures.

Isolate the Fault

This means to restrict the problem to the smallest section or part of a system or circuit as possible. It may be possible to limit the fault to a single block of a system, to a single circuit board, single circuit, or component. This is usually done by substituting a known good assembly whenever possible. Substitution is a time saver because no time is wasted troubleshooting a working subassembly.

Signal Tracing

When signal tracing, the defective circuit should be divided in half. When the signal checks good at the middle of the circuit, you can disregard the first half of the circuit. Continue to divide the circuit in half until one of your test points reveals a defect.

This procedure suggests the oscilloscope as best suited for troubleshooting. However, with digital circuits and LED indicating devices, the logic pulser is a valuable test instrument. It is easier to use and takes less time to set up and use than a signal generator. The logic probe is quicker and easier to use than the oscilloscope.

When the individual stages do not have LED readouts, a combination of the logic probe and logic pulser can be used for troubleshooting.

Once a defect has been discovered, back track the signal path until you find the last known good signal. Now that you know between which test points the fault lies, it is only a matter of a short time to isolate to the exact component causing the problem.

In analog circuits, the voltmeter and then the ohmmeter would be used. In digital circuits, the voltmeter, ohmmeter, logic pulser, and logic probe can all be used effectively.

The oscilloscope is a valuable aid when troubleshooting both analog and digital circuits.

Corrective Action

Once the fault has been isolated and a visual inspection doesn't yield results, the component part (usually a chip) should be replaced with a known good part. When you think you have the problem corrected run a complete functional test. This will ensure that the fault that you were troubleshooting did not mask another problem in the system.

Things to Remember

When troubleshooting, never take anything for granted. Also, there are no substitutes for common sense and good vision. Use all of your senses when troubleshooting.

You can detect a faulty installation or component by sight, smell, and touch. The senses of smell and sight are especially helpful because many times you can detect a problem and shut the circuit down before the equipment is severely damaged.

The most common problems that are overlooked are equipment not plugged in, blown fuse, or not properly interconnected. These are all classified as operator error. They don't require advanced technical skills to find. There are other operator faults and to ensure against them a second test run should be done. This is to make sure that a real circuit fault exists, before you start troubleshooting. Nothing is as bad as wasting time trying to fix a piece of equipment that does not have a problem.

After operator error, the most common problems are caused by a malfunctioning power supply. These problems are usually easily isolated because they cause multiple circuit faults.

Service Technician

The problems found by most service technicians are real component failures. This is because the equipment, in most cases, was operating properly when the problem occurred.

However, there are a large number of faults that occur between or during powering up and powering down the equipment. This is usually caused by surge currents upon initial turn on.

The service technician can usually ignore the possibility of wrong parts, incorrectly installed parts, solder bridges, and no solders since the equipment did operate properly before the failure.

Problems that are intermittent are extremely hard to find. These problems are usually caused by cold solder connections, rosin connections, or a loose connection. During a visual inspection, if you see a solder connection that doesn't look good, it may save you time to reheat the joint as part of the visual inspection. These problems are common to both the assembly and service technician.

In the following experiments, you should assume the position of an assembly technician.

Later, if your instructor desires, you can assume that you are a service technician.

Procedure

1. Connect the circuits as shown in Figure 33-1. The **dashed** lines indicate the jumper wires that you must install.

2. Set the 8-position dip switch in Block 1 to 2 and 4 up.

3. Turn the trainer on and observe the LEDs in Block 1. Examine the schematic diagram of the circuit you wired for this experiment.

4. Is the circuit operating properly?

   ____________.

5. If the circuit is NOT operating properly, what are the specific malfunctions noted?

   ____.

6. List the most probable cause of the malfunction. Continue to list possible causes for the problem or problems observed.

   ____

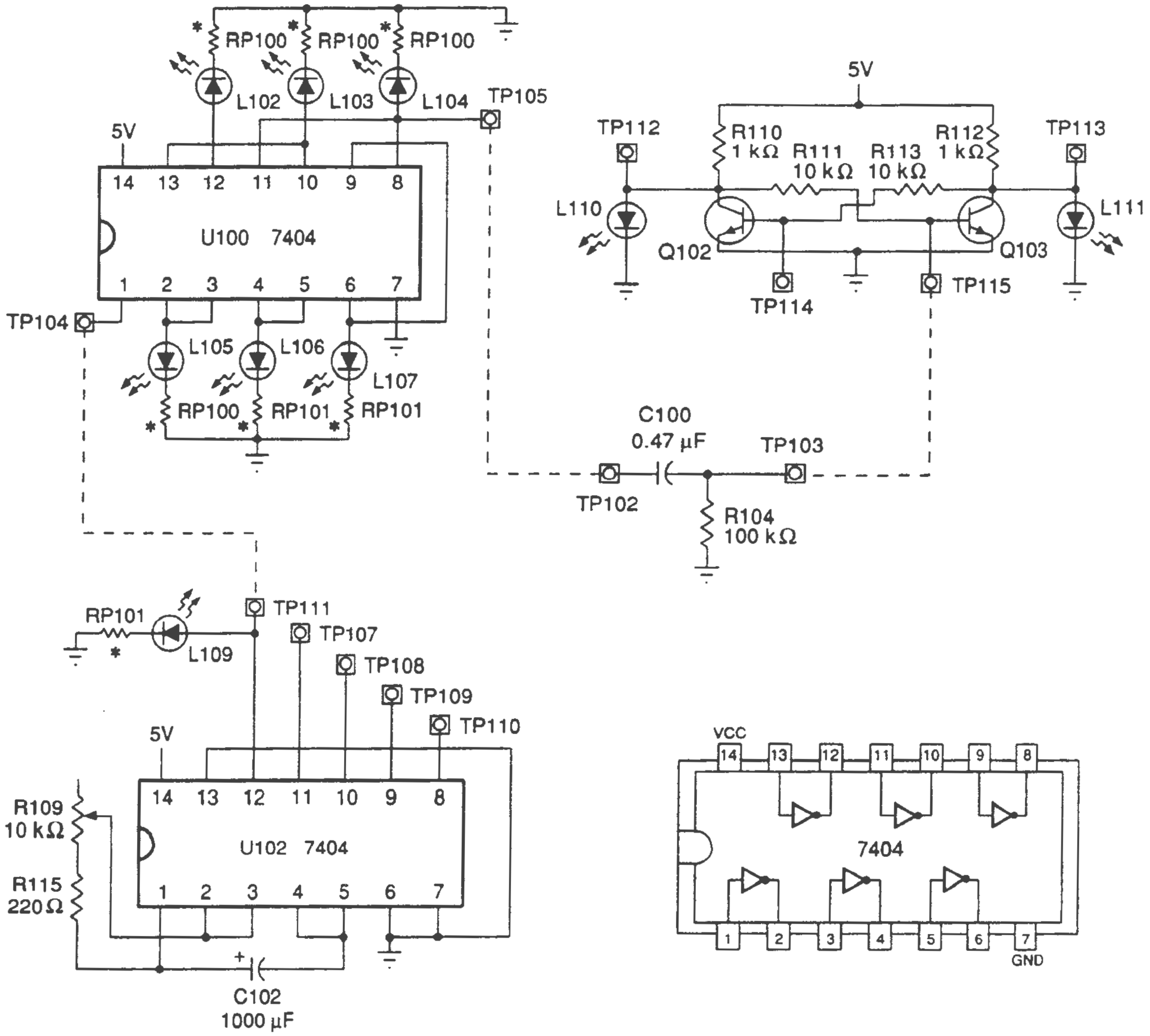
   ____.

7. Which test instrument would you use first to troubleshoot this problem?

   ____________________.

8. Why did you choose this test instrument to use first?

   ____.



* Resistors installed on ETB-6201-A only.

Figure 33-1

9. Which TP is your first choice to start your troubleshooting procedure?

_______________________.

10. Was your first problem diagnosis correct?

___________.

If your first choice proved to be incorrect, or the circuit has multiple faults, continue troubleshooting until you isolate all of the faults to their specific cause.

11. List the corrective action proposed for each fault noted.

____

____.

12. Perform the corrective action proposed in the previous step.

13. Which, if any, of your proposed corrective actions restored circuit operation?

____.

As you read the summary, refer to Figure 33-2.

Summary

In this circuit, you wired the digital clock output to the input of the hex inverter. Next, you wired the output of the hex inverter to the bistable multivibrator. All of these circuits are contained in Block 1.

Then you turned the trainer on and observed the operation of the LEDs in these circuits. You should have noted that the clock was not operating. Next, you should have noticed that both LEDs in the bistable multivibrator are on.

You should have realized that since some of the LEDs are lit, that 5 volts and ground are applied to the circuit board.

This indicates a possibility of at least two problems. First, the clock is not working. Second, one of the LEDs in the bistable multivibrator circuit should be lit since they are complementary outputs.

At this point, you can elect to troubleshoot either the clock or the multivibrator.

Your first step should be to isolate the circuit that you are going to troubleshoot. For this discussion I decided to isolate the clock by disconnecting the jumper wire from the output of the clock. This removes the load from the digital clock and eliminates the possibility that the digital clock is simply being overloaded by a fault in the hex inverter or bistable multivibrator.

Next, there appears to be two real causes for the clock to be inoperative. The clock could be malfunctioning or simply out of adjustment. The clock could be adjusted so that the clock's LED is locked low.

By visual inspection, it is obvious that the clock adjust potentiometer is not turned to either extreme. Therefore, it is unlikely that the clock is simply locked low.

To function, the clock requires both 5 volts and ground. If either of these are missing the clock will not operate. There is also the real possibility that one or more of the components are defective.

According to the schematic diagram the 7404 chip requires 5 volts at pin 14 and ground at pin 7.

To troubleshoot a live (on) circuit a voltmeter, oscilloscope, logic probe, and logic pulser can be used. To troubleshoot a dead (off) circuit an ohmmeter should be used.

A voltmeter check shows that 5 volts is not applied to pin 14. This could mean that the foil path is either open or shorted, or it could mean that the 5 volt supply is defective. Since some of the LEDs are working, it is unlikely that the 5 volt power supply is defective.

Next, you should turn the trainer off and with an ohmmeter check for a short to ground at pin 14 and continuity between pin 7 and ground. Since pin 14 is not shorted and pin 7 is grounded, the ohmmeter check eliminated both possibilities as the circuit fault.

Then, a continuity check between pin 14 and the 5 volt supply confirms an open. By visual inspection or the ohmmeter, divide the foil path in half and check for continuity on both halves of the foil path. You can continue to divide the foil path in half, until you discover the exact cause of the open. You can also reapply power and use a voltmeter to find the exact cause of the fault.

This is accomplished by starting at pin 14 of the chip and measuring for voltage along the foil path until you measure 5 volts. In this case, on one side of a switch you measure 5 volts and on the other side of the switch there is no 5 volts. This is because switch 5 is turned off.

Many suspected circuit faults are a result of operator error. Always, ensure that an actual circuit fault exists by running a functional test on the suspected circuit or equipment before starting your troubleshooting procedures.

Turning switch 5 on causes the clock LED to start blinking. Now that the clock is operating, you should reconnect the jumper wire to the clock's output. This causes the hex inverter LEDs to blink at the clock rate, but the multivibrator circuit is still inoperative.

Again, a possible cause is that there is a defective component, wrong voltage, or the circuit ground is open.

A voltmeter check at the collector of either transistor shows that voltage is applied to the circuit. A voltage check on each side of the collector resistors shows that there is a voltage drop. However, neither transistor is saturated. A voltmeter check at the emitter shows that there is voltage applied to the emitters.

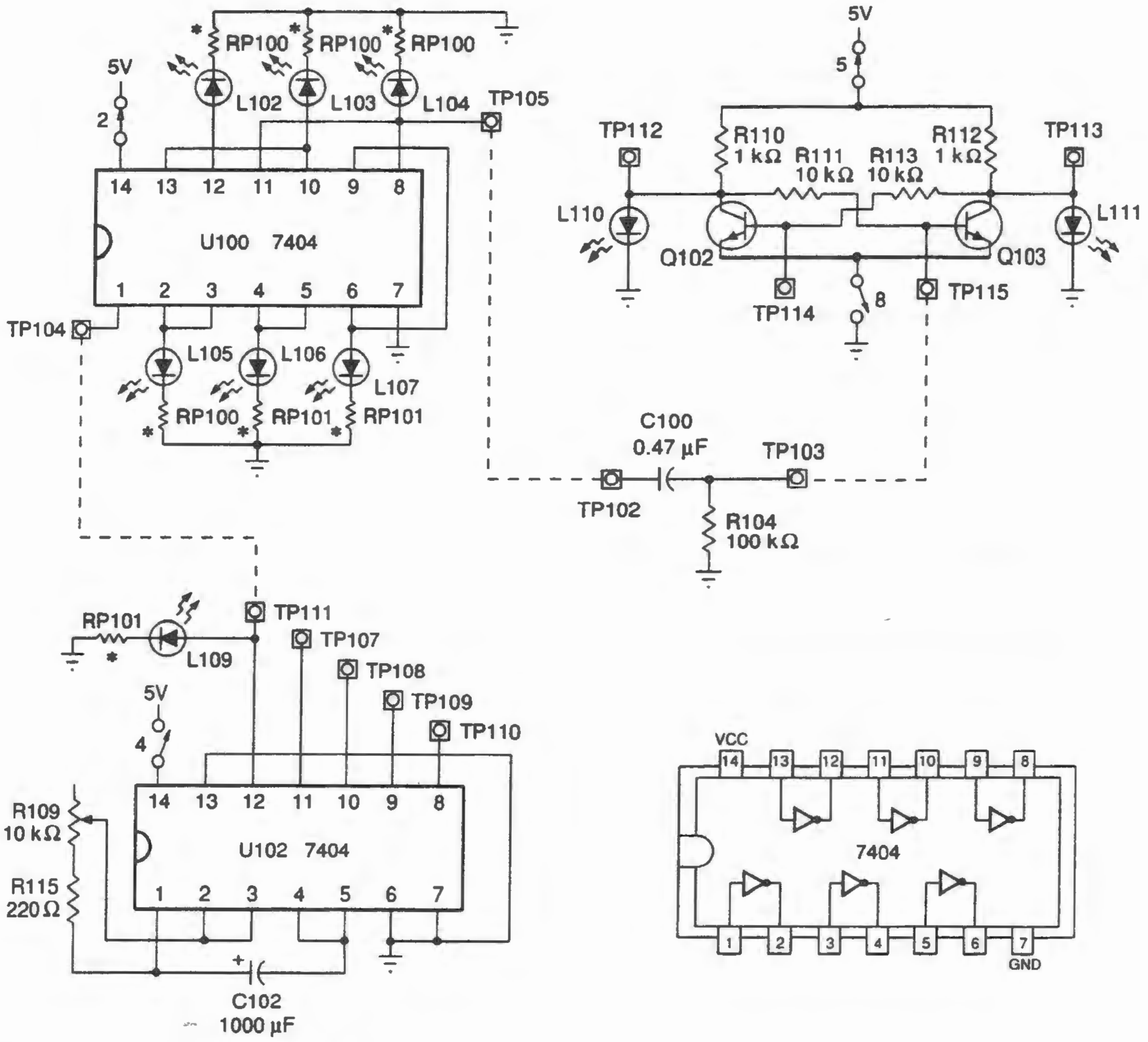
A check of the schematic shows that the emitters are grounded and should not have an applied voltage. The circuit started operating because you provided a ground through the voltmeter. In other words, you bypassed the open with your meter connections. By visually following the foil path (circuit run) you find that ground should be applied through switch 8. This step may or may not have happened depending on the type of voltmeter used to check voltage.

Since switch 8 is open the bistable multivibrator is deprived of its normal ground path. Closing switch 8 causes one of the LEDs to light and the circuit blinks at the clock frequency.

A complete functional test now shows that with dip switches 2, 4, 5, and 8 closed, the circuit operates properly.

Remember, the most important points in troubleshooting are to develop a plan, follow the plan, pay attention to details, be observant, and always use caution and common sense.

Always, be consistent in your approach to troubleshooting. Make sure that you understand what the equipment or circuit is supposed to do when operating properly.



* Resistors installed on ETB-6201-A only.

Figure 33-2

Experiment 34

The AND Logic Function

Purpose

To evaluate the AND logic function.

To troubleshoot the AND logic circuit.

To restore a circuit to its proper operation.

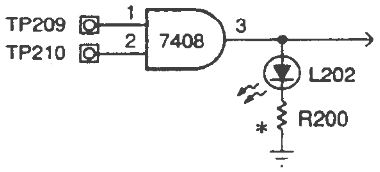
Introduction

In this experiment, the circuit should provide the AND logic function. The circuit used in this experiment is located in Block 2 of the circuit board.

Procedure

1. Connect a jumper wire between TP914 and TP209.

   Connect another jumper wire between TP913 and TP210



* Resistors installed on ETB-6201-A only.

Figure 34-1

2. Set SW200 to 1, 3, 5, and 7 up.
3. Turn the trainer on and observe the LEDs in block 2.
4. Cycle the two Boolean variables through their four possible input combinations. TP209 is A and controlled by data SW1. TP210 is B and controlled by data SW2.
5. Plot the truth table outputs assuming that a lit LED indicates a binary 1.

A	B	X
0	0	
0	1	
1	0	
1	1	

Figure 34-2

6. Is the circuit operating as an AND gate?

   ____________________ .

---

* Resistor may or may not be installed.

7. If the circuit is not operating as an AND gate, list the problem or problems that you noted.

    ____________________ .

    ____________________ .

8. If there is a problem, list what you think are the probable causes of the problem?

    ____________________ .

    ____________________ .

9. Which piece of test equipment do you select to start your troubleshooting?

    ____________________ .

10. Why did you choose the test equipment that you listed in step 9?

    ____ .

11. Which is your first choice for a starting test point?

    ____________________ .

12. Did the first test confirm your circuit diagnosis?

    ____________________ .

13. If the cause of the problem is still unknown, list the TP measurements in the order that you will use in determining the exact cause of the circuit's malfunction.

    ____________________ .

    ____________________ .

    ____________________ .

14. What is the exact cause of the problem?

____.

15. What is your proposed corrective action?

____.

16. Perform your recommended corrective action.

17. Is proper circuit operation restored?

__________________.

18. If you think that the circuit is now operating properly, rerun a complete functional test on the circuit.

19. If you discovered another problem or if the circuit is still malfunctioning, continue your troubleshooting procedures.

20. Once the circuit is restored to proper operation, remove the jumpers, set all switches in block 2 to their low positions, and read the summary.

Summary

The logic function performed in this experiment should be the AND function as indicated by the amber LED (L202).

It would have been very helpful if you had remembered that the 7408 chip is a Quad-AND and that the AND logic function provides an output only when all of its inputs are high.

During your initial circuit test none of the LEDs should have lit. This suggests the possibility of a defective chip, defective LED, missing voltage, or open ground connection.

I would have picked the voltmeter, or logic probe, and checked for 5 volts applied to pin 14 of the 7408. Next, I would have checked for continuity between pin 7 of the 7408 and ground with an ohmmeter.

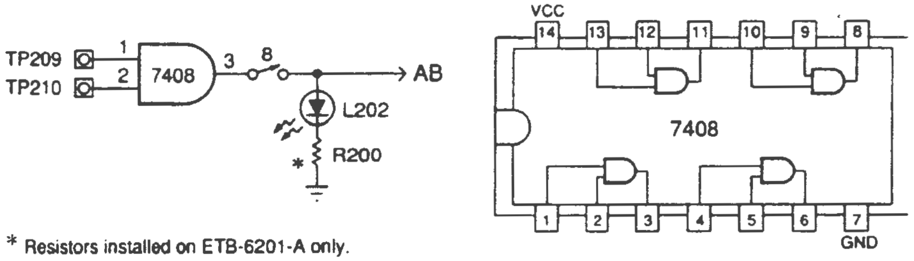
Remember, that an ohmmeter is used on circuits that are turned off. The voltmeter, ammeter, oscilloscope, logic pulser, and logic probe are all used on activated circuits.

Then, I would have set both inputs high and measured the output (pin 3) of the 7408 for a high. Once I saw the high at pin 3, I would have measured the voltage applied to the anode of the LED.

This would have shown that even though the AND gate had a high output, the output voltage did not reach the LED.

A continuity check reveals an open between pin 3 of the IC and LED (L202). By back tracking the foil path, you would have found that the open is because switch 8 is open.

I would then close switch 8, which would have lit the LED. Next, I would cycle the Boolean variables through all four of the possible inputs to ensure that only a 1 1 input results in L202 being lit.



* Resistors installed on ETB-6201-A only.

Figure 34-3

Experiment 35
The OR Logic Function

Purpose

To evaluate the OR logic function.

To troubleshoot the OR logic circuit.

To restore a circuit to its proper operation.

Introduction

In this experiment, the circuit should provide the OR logic function. The circuit used in this experiment is located in Block 2 of the circuit board.

Procedure

1. Connect TP211 to data switch 1 (TP914).

   Connect TP215 to data switch 2 (TP913).

2. Set SW200 to 4, 5, 6, and 8 up.

3. Turn the trainer on and observe the LEDs in block 2.

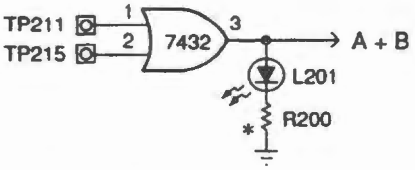


Figure 35-1

4. Cycle the two data switches through all four of their possible input combinations.

5. Plot the truth table outputs assuming that a lit LED (L201) indicates a binary 1.

A	B	X
0	0	
0	1	
1	0	
1	1	

Figure 35-2

6. Is the circuit operating as an OR gate?

________________________.

7. If the circuit is not operating as an OR gate, list the problem or problems that you noted.

________________________.

________________________.

8. If there is a problem, list what you think are the probable causes of the problem?

________________________.

________________________.

9. Which piece of test equipment do you select to start your troubleshooting?

____________________.

10. Why did you choose the test equipment that you listed in step 9?

____ .

11. Which is your first choice for a starting test point?

____________________.

12. Did the first test confirm your circuit diagnosis?

____________________.

13. If the cause of the problem is still unknown, list the TP measurements in the order that you will use in determining the exact cause of the circuit's malfunction?

______________________.

______________________.

______________________.

14. What is the exact cause of the problem?

______________________.

15. What is your proposed corrective action?

______________________.

16. Perform your recommended corrective action.

17. Is proper circuit operation restored?

__________________.

18. If you think that the circuit is now operating properly, rerun a complete functional test on the circuit.

19. If you discovered another problem or if the circuit is still malfunctioning, continue your troubleshooting procedures.

20. Once the circuit is operating properly, remove the jumpers, set all switches in block 2 to their low positions and read the summary.

Summary

The logic function performed in this experiment should be the OR function.

It would have been very helpful if you had remembered that the 7432 chip is a Quad-OR and that the OR logic function provides an output anytime any or all of its inputs are high.

During your initial circuit test, the amber and clear LEDs should have lit when the inputs are both equal to 1. Since this condition is true of the AND, OR, and XNOR it isn't useful information. When the inputs are mismatched (01 or 10) either the amber or clear LED lit. This is also not the OR function. Therefore, the circuit is defective.

This suggests the possibility of a defective chip, defective LED, missing voltage, or open ground connection.

Since some of the LEDs are lighting and following the changing inputs, I would have checked the schematic to see what causes the the LEDs to light. Once you see that they are connected directly to the inputs, you should realize that they don't have anything to do with the OR operation.

Next, I would use the voltmeter, or logic probe, and check for 5 volts at pin 14 of the 7432. Then, I would check for continuity between pin 7 of the 7432 and ground with an ohmmeter.

You should have remembered to turn the trainer off before taking measurements with an ohmmeter.

The 5 volt test would have shown that the power supply voltage is missing. The ohmmeter test confirms that ground is connected to pin

By following the foil path from pin 14 through closed switch 4, you would have discovered that switch 1 is open. This prevents 5 volts from reaching pin 14. Closing switch 1 and rechecking the voltage at pin 14 would have shown that 5 volts is now properly applied.

A functional test of the circuit shows that the circuit still does not provide the OR function.

A check of the schematic shows that the output of the OR gate is pin 3 of the 7432 chip. By applying inputs, 01, 10, or 11 and checking at pin 3 with a logic probe, oscilloscope, or voltmeter you see that the gate is functioning properly (output high). By following the foil path or examining the schematic, you find that the green LED (L201) is connected to the output (pin 3) of the 7432 chip.

A voltage check at the anode of the green LED (L201) shows that there is no voltage applied. A continuity check between the anode of the green LED and pin 3 reveals an open in the line. A check of the foil path shows that switch 7 is the reason for the open foil path.

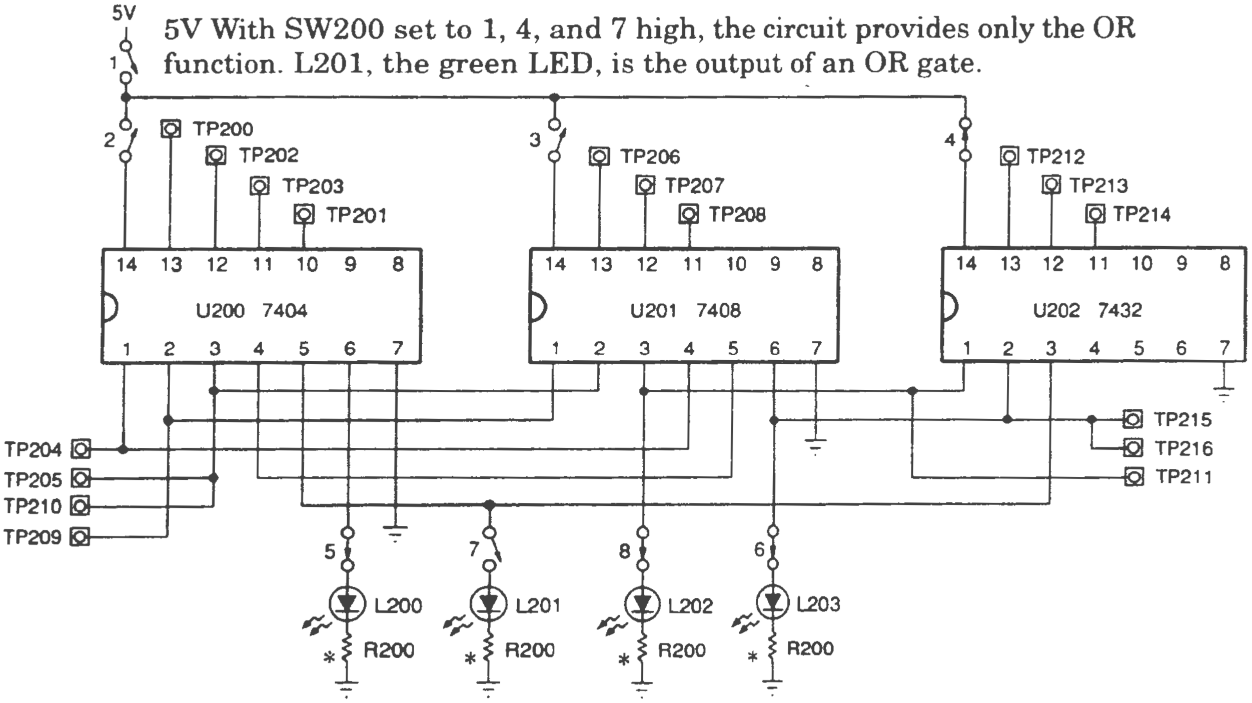
Closing switch 7 lights the green LED.

A functional test of the circuit shows the green LED (L201) is now reflecting the proper operation of an OR gate.

Therefore, this circuit had two faults. Switch 1 opened the supply voltage to block 2, which prevented 5 volts from reaching pin 14 of the 7432 chip. Switch 7 opened the foil path between the output of the OR gate (pin 3) and the LED.

L202 can be disabled using switch 8 and L203 can be disabled using switch 6. With switches 6 and 8 off, the only LED responding to the changing inputs is L201.

5V With SW200 set to 1, 4, and 7 high, the circuit provides only the OR function. L201, the green LED, is the output of an OR gate.



* Resistors installed on ETB-6201-A only.

Figure 35-3

Experiment 36
Detector Circuits

Purpose

To evaluate detector circuits.

To troubleshoot equality and inequality detector circuits.

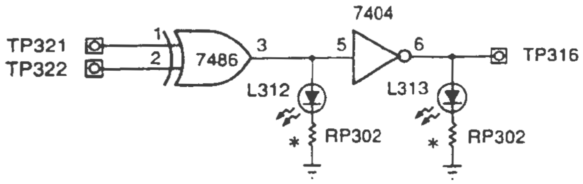
To restore a circuit to its proper operation.

Introduction

In this experiment, the circuit should provide both detector functions (XOR and XNOR). The chips used in this experiment are U302 and U305, located in Block 3 of the circuit board.

Procedure

1. Connect TP321 to TP914 (data switch 1) and TP322 to TP913 (data switch 2).
2. Set SW301 to 4 and 8 up.
3. Turn the trainer on and observe the LEDs in block 3.



* Resistors installed on ETB-6201-A only.

Figure 36-1

4. Cycle data switches 1 and 2 through the four possible input combinations.

5. Plot the truth table outputs assuming that a lit LED indicates a binary 1.

A	B	L312	L313
0	0		
0	1		
1	0		
1	1		

Figure 36-2

6. Is the circuit operating as either an equality detector or an inequality detector?

__________________ .

7. If the circuit is not operating properly, list the problem or problems that you noted.

________________________ .

________________________ .

8. If there is a problem, list what you think are the probable causes of the problem?

________________________ .

________________________ .

9. Which piece of test equipment do you select to start your troubleshooting?

__________________ .

10. Why did you choose the test equipment that you listed in step 9?

    ____.

11. Which is your first choice for a starting test point?

    ______________.

12. Did the first test confirm your circuit diagnosis?

    ______________.

13. If the cause of the problem is still unknown, list the TP measurements in the order that you will use in determining the exact cause of the circuit's malfunction?

    ______________.

    ______________.

    ______________.

14. What is the exact cause of the problem?

    ______________.

    ______________.

15. What is your proposed corrective action?

    __________________.

    __________________.

16. Perform your recommended corrective action.

17. Is proper circuit operation restored?

    ______________.

18. If you think that the circuit is now operating properly, rerun a complete functional test on the circuit.

19. If you discovered another problem or if the circuit is still malfuncting, continue your troubleshooting procedures.

20. Once the circuit is operating properly, remove the jumpers, set all switches in block 3 to their low positions and read the summary.

Summary

In this experiment, one of the LEDs should be lit only when the inputs are equal (00 and 11). Another LED should be lit only when the inputs are not equal.

It would have been very helpful if you had remembered that the 7486 chip is a Quad-XOR. Also, that the XOR logic function provides an output when its inputs are not equal.

During your initial check, none of the LEDs lit.

There are two circuit configurations in block 3 that can perform both of the functions specified. However, with the inputs applied to TP321 and TP322, only one of the functions will work.

After examining the circuit's schematic (wiring diagram), you should check pin 14 of both U305 and U302 for 5 volts. Next, you should check pin 7 of both chips for ground.

You should have found the grounds to be connected, but 5 volts missing from both chips.

A check of the 5 volt supply to the board would have confirmed the presence of 5 volts on the circuit board. Next, a continuity check from pin 14 of each chip to the 5 volt supply would confirm that both foil paths are open. By tracing the foil paths of each chip separately, you should have found that switch 3 caused the open to pin 14 of U305. Switch 1 caused the open to pin 14 of U302.

After closing the switches (1 and 3) and confirming that V_{CC} is restored, you should have confirmed that the output of U305 (pin 3) provided the proper output for an exclusive OR gate. This can be confirmed by monitoring pin 3 while you change the input variables.

When you confirm that the gate is operating properly you see that one of the LEDs is still not responding. Next, you should have checked for continuity between pin 3 of U305 and pin 5 of U302 . Once you established that the line is open, a careful check of the foil path shows that switch 5 is the problem. Once switch 5 is closed, the green LED (L312) is lit for inputs 01 and 10. The red LED (L313) is lit for inputs 00 and 11.

Therefore, the green LED (L312) provides an output when the inputs are not equal. That is the proper logic operation for an Exclusive OR (XOR). It is also called an inequality detector or comparator circuit.

The red LED (L313) is lit when the inputs are equal. This is the complement (NOT) function of the XOR. It is also called an equality detector or the XNOR logic function.

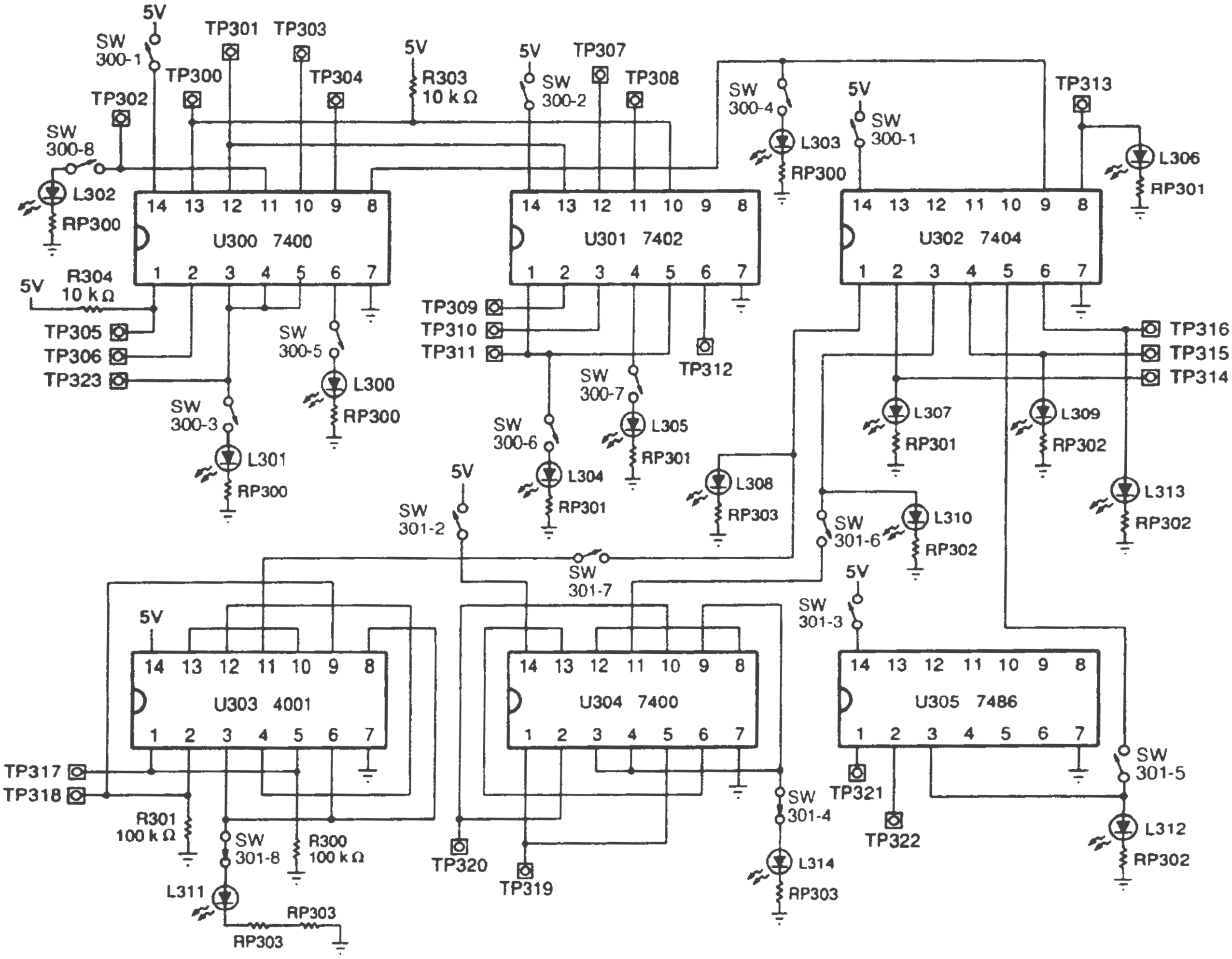
This circuit had 3 faults or problems. Both chips (U302 and U305) were missing the supply voltage. The foil path between pin 3 of U305 and pin 5 of U302 was open.

There are several approaches to troubleshooting a circuit. However, the key to early success is to be consistant in your approach to troubleshooting. As you gain experience, you will see that there are many shortcuts that provide good results.

For example, take all voltage measurements at one time. This saves time in changing test equipment, as well as, not having to cycle the equipment on and off several times. In addition, many different types of equipment have a built in time delay. This circuit may ensure that the power supplies are stable or that the unit is up to temperature before it can be operated. Waiting for the delay circuits to time out every time you want to take a measurement can add considerable time to the troubleshooting and repair process.

At this time, you should concentrate on developing a troubleshooting technique. Later, as you become familiar with the equipment and techniques used, your time to repair and evaluate a circuit will decrease.

In troubleshooting, as with most learned skills, proficiency and efficiency are obtained through practice, practice, and more practice.



* Resistors installed on ETB-6201-A only.

Figure 36-3

Experiment 37
A Binary Storage Device

Purpose

To evaluate the storage capability of a digital device.

To troubleshoot a 4-bit register.

To restore a circuit to its proper operation.

Introduction

In this experiment, the circuit should have 4-bit storage capability. The four bits should be programmable in the 8, 4, 2, 1 binary weighted code.

The chip used in this experiment is U400, located in Block 4 of the circuit board.

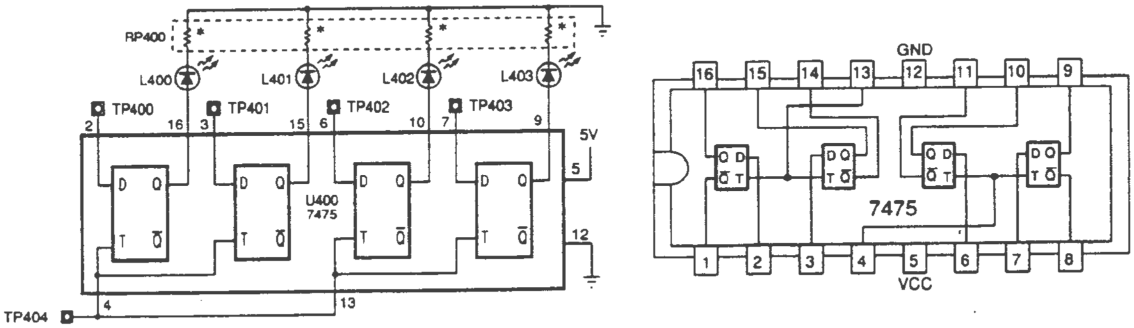
Procedure

1. With jumper wires connect TP400, TP401, TP402, and TP403 to the four data switches (TP914, TP913, TP912, and TP911).

   Connect a jumper wire from TP404 to TP909.

   Set all data switches low.

2. Set SW400 to 1, 3, 6, 7, and 8 up.



* Resistors installed on ETB-6201-A only.

Figure 37-1

3. Turn the trainer on and observe the LEDs in block 4.

4. Cycle the data switches through the possible input combinations ($2^4 = 16$).

5. Plot the truth table outputs assuming that a lit LED indicates a binary 1.

INPUTS				OUTPUTS			
SW1	SW2	SW3	SW4	L400	L401	L402	L403
0	0	0	0				
0	0	0	1				
0	0	1	0				
0	0	1	1				
0	1	0	0				
0	1	0	1				
0	1	1	0				
0	1	1	1				
1	0	0	0				
1	0	0	1				
1	0	1	0				
1	0	1	1				
1	1	0	0				
1	1	0	1				

Figure 37-2

6. Is the circuit operating as a binary storage circuit?

________________.

7. If the circuit is not operating properly, list the problem or problems that you noted.

____.

____.

8. If there is a problem, list what you think are the probable causes of the problem?

____ .

____ .

9. Which piece of test equipment do you select to start your troubleshooting?

____________________.

10. Why did you choose the test equipment that you listed in step 9?

____ .

11. Which is your first choice for a starting test point?

_______________.

12. Did the first test confirm your circuit diagonisis?

_______________.

13. If the cause of the problem is still unknown, list the TP measurements in the order that you will use in determining the exact cause of the circuit's malfunction?

____________________.

____________________.

____________________.

14. What is the exact cause of the problem?

____ .

____ .

15. What is your proposed corrective action?

____ .

____ .

16. Perform your recommended corrective action.

17. Is proper circuit operation restored?

____________________.

18. If you think that the circuit is now operating properly, rerun a complete functional test on the circuit.

19. If you discovered another problem or if the circuit is still malfuncting, continue your troubleshooting procedures.

20. Once the circuit is operating properly, remove the jumpers, set all switches in block 4 to their low positions and read the summary.

Summary

In this experiment U400 is a 7475 4-stage D-type flip-flop.

In normal operation, when you applied power none of the LEDs should be lit. However, when you cycled the data switches to their up positions the LEDs should have indicated which inputs are high and which inputs are low. Again a lit LED is assumed to indicate the presence of a binary 1.

Your first indication of a problem should have been when the LEDs did not follow the inputs.

The probable causes are defective chip, all four LEDs defective, missing voltage, or a ground problem.

Another cause could be that the flip-flops are not conditioned to respond to a signal applied to the set (D) inputs.

A voltmeter check would have revealed that 5 volts is applied to pin 5 and that the data switches are changing from high to low at pins 2, 3, 6, and 7 of U400 when switched.

An ohmmeter check would have confirmed that ground is applied to pin 12.

Assume that the chip is not defective unless told otherwise by the instructor.

Once you establish that voltage, ground, and the input signals are good, it is time to think about how a D-type flip-flop works.

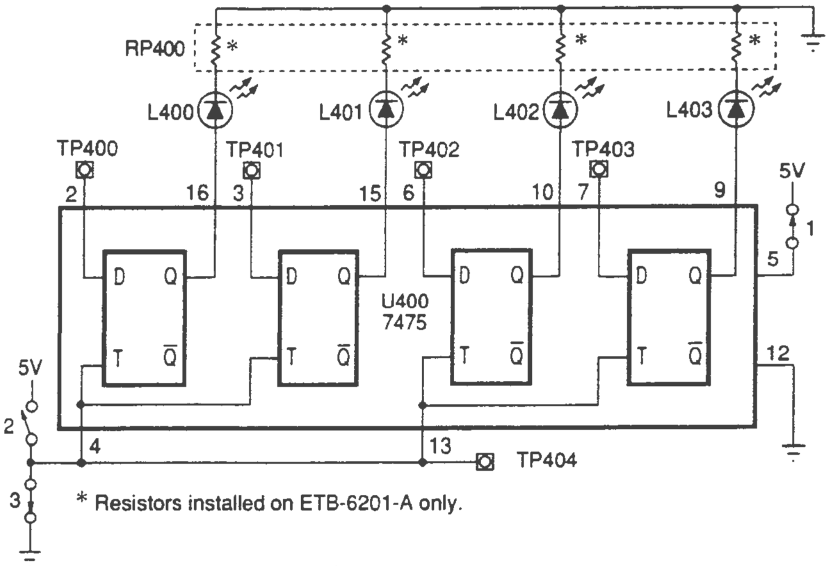
You should recall that to program a change to the D inputs the toggle (T) input should be locked high. A check of the T inputs reveals that the T inputs are all grounded.

By examining the schematic you see that all of the T inputs are tied together and to the A logic function switch (TP909). By disconnecting the jumper wire from A and measuring with an ohmmeter you can eliminate A (TP909) being grounded as the problem.

Finally, by following the foil paths from the T inputs, you find that the ground is coming through switch 3 of the dip switch. Once you open switch 3, you can measure the T inputs and see that ground has been removed.

A complete test now shows that the LEDs are responding properly to the ones and zeros applied through the four data switches.

SW 1 up is the only requirement to operate this D-type flip-flop (7475 chip). The required high for pin 4 of the IC is supplied through TP909 which is connected to the $\overline{A}$ logic position.



* Resistors installed on ETB-6201-A only.

Figure 37-3

Experiment 38
Parallel Storage Register

Purpose

To evaluate the storage capability of a register.

To troubleshoot a 4-bit register.

To restore a circuit to its proper operation.

Introduction

In this experiment, the circuit should provide 4-bit storage capability. The four bits should be programmable in the 8, 4, 2, 1 binary weighted code.

The chip used in this experiment is U503, located in Block 5 of the circuit board.

Procedure

1. Connect the jumper wires as listed below.

PINS ON 7495	TO	FUNCTION
13 (TP511)		L_1 (TP902)
12 (TP512)		L_2 (TP903)
11 (TP513)		L_3 (TP904)
10 (TP514)		L_4 (TP905)
5 (TP518)		DATA SW 4 (TP911)
2 (TP-520)		DATA SW1 (TP914)
3 (TP517)		DATA SW 2 (TP913)
4 (TP521)		DATA SW3 (TP912)
8 (TP515)		(TP900)

Make sure all data switches are switched low.

2. Set SW400 in block 4 to 1, 6, and 8 up.

Set SW500 in block 5 to 1, 2, 3, 4, 5, 6, 7, and 8 up.

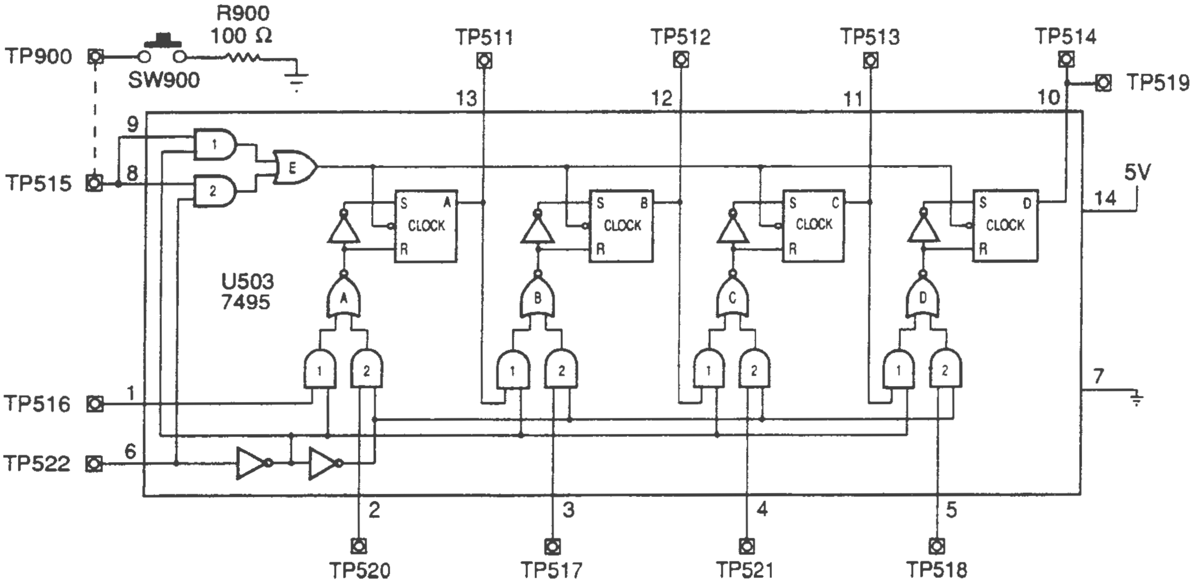


Figure 38-1

3. Turn the trainer on and observe the LEDs on the main trainer.

4. Cycle the data switches through all of their possible input combinations. Each time you move a data switch, SW900 must be cycled to load the count.

5. Plot the truth table outputs assuming that a lit LED indicates a binary 1.

INPUTS				OUTPUTS			
SW1	SW2	SW3	SW4	L400	L401	L402	L403
0	0	0	0				
0	0	0	1				
0	0	1	0				
0	0	1	1				
0	1	0	0				
0	1	0	1				
0	1	1	0				
0	1	1	1				
1	0	0	0				
1	0	0	1				
1	0	1	0				
1	0	1	1				
1	1	0	0				
1	1	0	1				

Figure 38-2

6. Is the circuit operating as a binary storage circuit?

________________ .

7. If the circuit is not operating properly, list the problem or problems that you noted.

____ .

____ .

8. If there is a problem, list what you think are the probable causes of the problem?

______________________________.

______________________________.

9. Which piece of test equipment do you select to start your troubleshooting?

______________________.

10. Why did you choose the test equipment that you listed in step 9?

____ .

11. Which is your first choice for a starting test point?

____________________.

12. Did the first test confirm your circuit diagnosis?

____________________.

13. If the cause of the problem is still unknown, list the TP measurements in the order that you will use in determining the exact cause of the circuit's malfunction?

______________________________.

______________________________.

______________________________.

14. What is the exact cause of the problem?

______________________________.

______________________________.

15. What is your proposed corrective action?

____.

____.

16. Perform your recommended corrective action.

17. Is proper circuit operation restored?

_______________.

18. If you think that the circuit is now operating properly, rerun a complete functional test on the circuit.

19. If you discovered another problem, or if the circuit is still malfuncting, continue your troubleshooting procedures.

20. Once the circuit is operating properly, remove the jumpers, set all switches in blocks 4 and 5 to their low positions and read the summary.

Summary

In this experiment U503 is a 7495 4-stage register. When the circuit is wired as listed in step 1, L1 should correspond to the input supplied by data switch 4. In this case, the value of L1 is the equivalent of a decimal 8. Therefore, L1 and data switch 4 represent the most significant bit (MSB).

You should not have been misled or distracted by the LEDs in block4 or block 5. You should have realized that you wired the 7495 chip to the LEDs on the main trainer board and not the LEDs in block 4 or block 5. The LEDs in block 4 are wired to U400. The LEDs in block 5 are wired to U500, U501, and U502.

In normal operation, when you apply power none of the LEDs should be lit. However, when you moved the data switches to their up positions and cycled SW900, the LEDs should have indicated which inputs are high and which inputs are low.

Your first indication of a problem should have been when some of the LEDs changed state when you moved the data switches, but didn't press SW900.

The probable causes are a defective chip, a wiring error, missing voltage, or a ground problem.

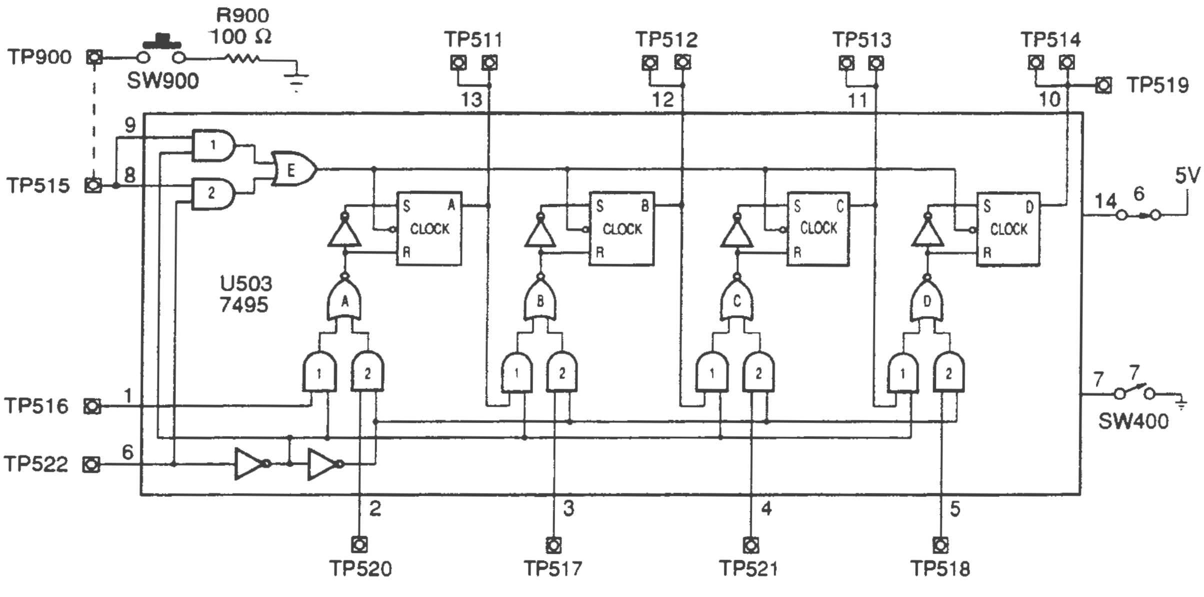
A voltmeter check would have revealed that 5 volts is applied to pin 14 and that the data switches are changing from high-to-low when switched.

An ohmmeter check would have shown that ground is missing from pin 7.

By following the foil path from pin 7, you should have found ground available through SW400 switch 7 to U503.

When you closed switch 7, the circuit should have been restored to proper operation.

A complete test now shows that the LEDs are responding properly to the ones and zeros applied through the data switches.



* Resistors installed on ETB-6201-A only.

Figure 38-3

Experiment 39
BCD Counter with Multiple Readouts

Purpose

To evaluate the operation of a BCD counter and its readouts.

To troubleshoot a counter/driver/multidisplay circuit.

To restore a circuit to its proper operation.

Introduction

In this experiment, the circuit should provide both a BCD and a decimal readout.

The chips used in this experiment are U700 and U701, located in Block 7 of the circuit board.

Procedure

1. Connect a jumper wire between TP700 and the clock TP906.

2. Set SW700 to 2, 4, 5, 6, and 7 up.

3. Turn the trainer on and observe the visual displays in block 7.

4. Is the circuit operating as a BCD and decimal counter?

   ____________.

5. If the circuit is not operating properly, list the problem or problems that you noted.

   ______________________________________.

   ______________________________________.

6. If there is a problem, list what you think are the probable causes of the problem?

   ______________________________________.

   ______________________________________.

7. Which piece of test equipment do you select to start your troubleshooting?

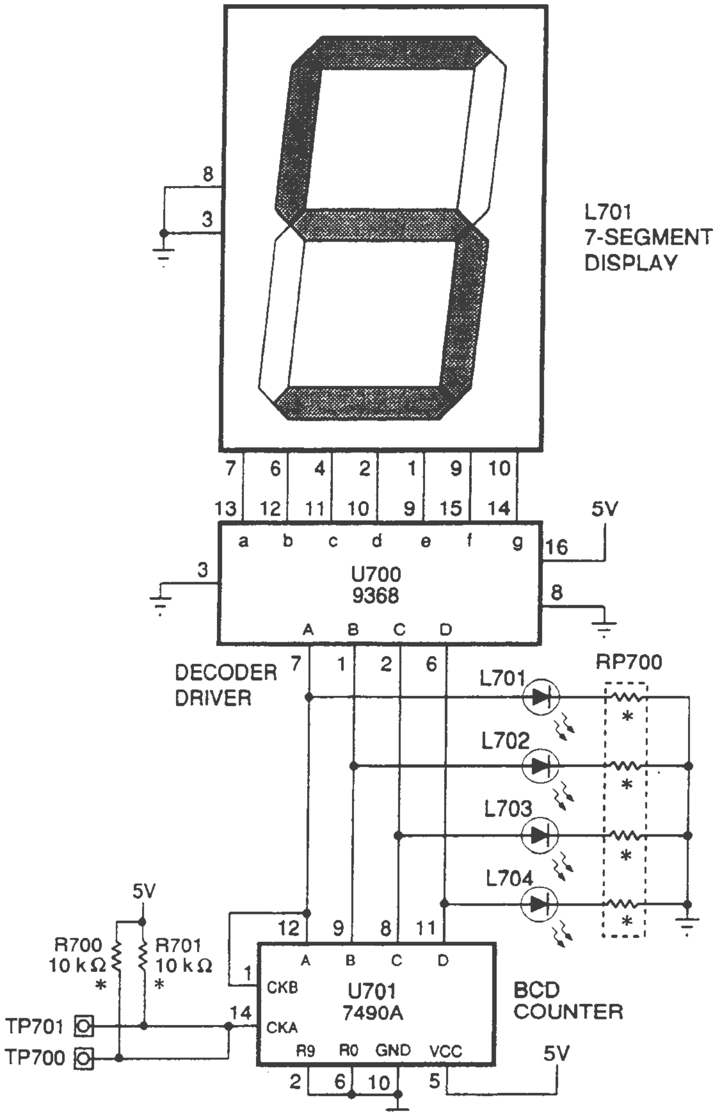
   __________________.

8. Why did you choose the test equipment that you listed in step 7?

   ____.

9. Which is your first choice for a starting test point?

   _______________.



* Resistors installed on ETB-6201-A only.

Figure 39-1

10. Did the first test confirm your circuit diagnosis?

    ________________.

11. If the cause of the problem is still unknown, list the TP measurements in the order that you will use in determining the exact cause of the circuit's malfunction?

    ________________.

    ________________.

    ________________.

12. What is the exact cause of the problem?

    ________________.

    ________________.

13. What is your proposed corrective action?

    ________________.

    ________________.

14. Perform your recommended corrective action.

15. Is proper circuit operation restored?

    ________________.

16. If you think that the circuit is now operating properly, rerun a complete functional test on the circuit.

17. If you discovered another problem or if the circuit is still malfunctioning, continue your troubleshooting procedures.

18. Once the circuit is operating properly, remove the jumpers, set all switches in block 7 to their low positions and read the summary.

Summary

In this experiment, U701 is a 7490 BCD counter. L701 should correspond to the LSB. In this example, the value of L701 is the equivalent of a decimal 1. Therefore, L701 is the LSB. In normal operation, when you apply power, the 7490 counter chip follows the clock rate and sequences through the LEDs at the BCD rate.

In other words, the LEDs should have counted from 0000 to 1001. The 7-segment display should have shown the decimal character equivalent to the BCD LED display.

Instead, what you observed is that the LEDs followed the clock pulses and properly displayed the BCD code. However, the 7-segment display did not display any characters.

The most probable cause of a total 7-segment failure is a defective driver chip, missing voltage to the driver chip, or a missing ground from either the driver chip or the 7-segment display.

The problem could not have been the clock or the 7490 chip because the LED display operated properly.

A voltmeter check shows that the driver chip has the proper voltage applied. It could also show that some of the segments should be lit because the inputs to the 7-segment device appear to be working properly. This also proves that ground to the driver chip U700 is properly connected.

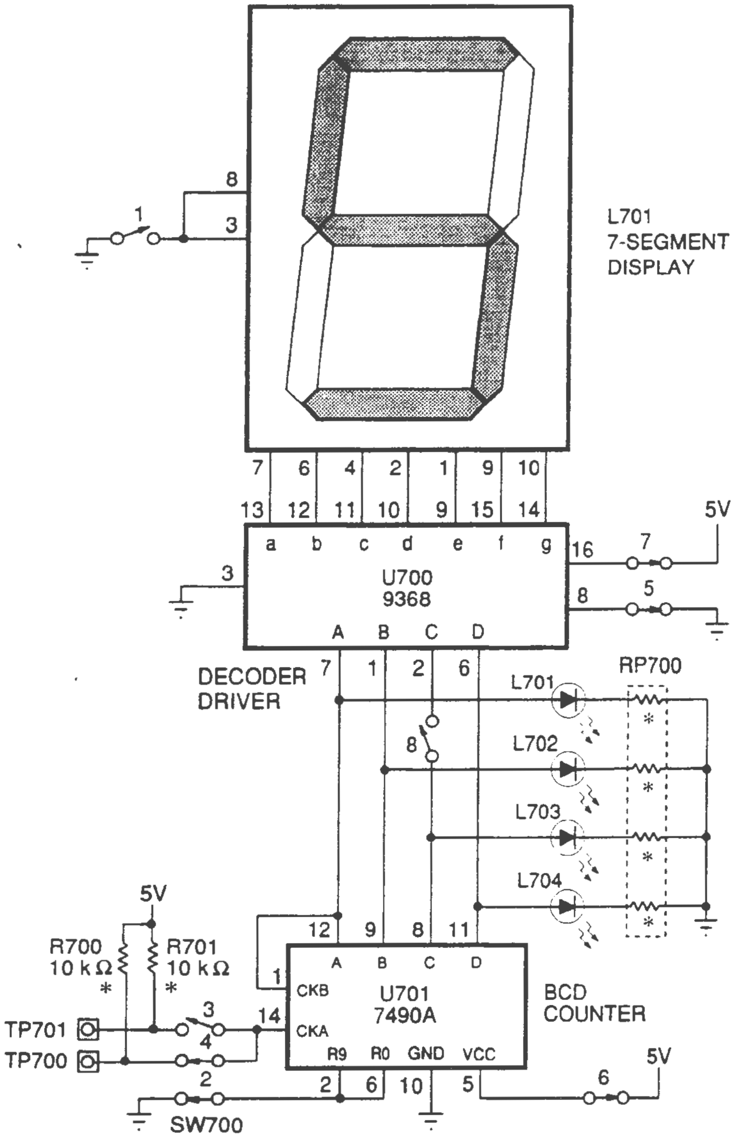
An ohmmeter check at pin 3 or pin 8 of the 7-segment display indicates a missing ground. Careful tracing of the foil path shows that ground is applied to L700 through switch 1 of the dip switch. Since the switch is open, ground never reaches the 7-segment display.

Closing switch 1 causes the 7-segment display to start working. However, on closer observation, you should have noticed that the 7-segment display is not always displaying the same digits as the LEDs. It is also not counting in the proper sequence for the decimal number system.

A voltage check of the inputs to U700 reveals that pin 2 is never gated. However, pin 8 of U701 is being gated. This can be proven using a volt meter, logic probe, or oscilloscope or simply assumed since L703 is being gated off and on.

A continuity check between pin 2 of U700 and pin 8 of U701 shows that there is an open. Carefully tracing the foil leads to an open switch 8 in block 7. Closing switch 8 causes the 7-segment display and the LEDs to indicate the same value at the same time.

Another full circuit test shows that the circuit is now operating properly.



* Resistors installed on ETB-6201-A only.

Figure 39-2

Experiment 40
Programmable Memory Circuit

Purpose

To evaluate the operation of a binary counter with RAM memory.

To troubleshoot a programmable memory circuit.

To restore a circuit to its proper operation.

Introduction

In this experiment, the circuit should provide both memory storage and a hexidecimal step counter.

The chips used in this experiment are U800, U801, and U802, located in Block 8 of the circuit board.

Procedure

1. Connect the jumper wires as listed below.

   TP800 to the A logic switch (TP910).

   TP801 to B(NOT) TP907

   TP802 to data switch 2 (TP913).

   TP803 to data switch 1 (TP914).

   TP804 to data switch 4 (TP911).

   TP805 to data switch 3 (TP912).

2. Set SW800 to switch 1, 2, and 4 up.

3. Turn the trainer on, and using the data switches, program sixteen 4-bit bytes into memory. Remember, to program this circuit, the A logic switch programs the step and the B logic switch loads the count. Remember also that the circuit has a volitile memory.

4. **The data switches and the LEDs should not be connected to the RAM chip at the same time.** Dip switches 5, 6, 7, and 8 control the LEDs. Switch "on" connects the LEDs and switch"off" disconnects the LEDs.

   After programming the data, remove the data line jumper wires and turn on the LEDs (SW800 5, 6, 7, and 8).

5. Is the circuit operating as a BCD or hexadecimal counter?

   ____________________.

6. If the circuit is not operating properly, list the problem or problems that you noted.

   ____.

   ____.

7. If there is a problem, list what you think are the probable causes of the problem?

   ____.

   ____.

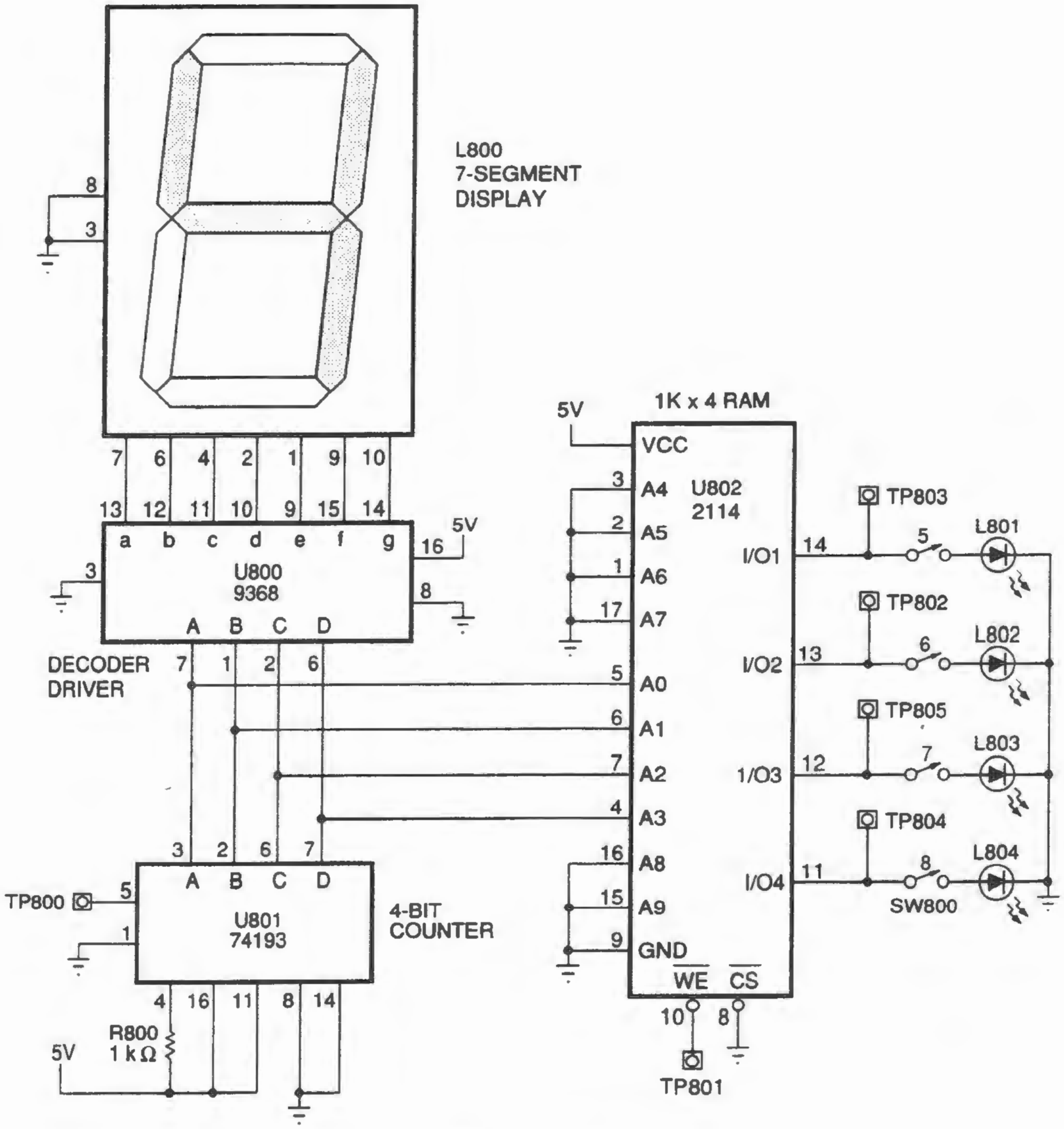


Figure 40-1A

ETB-6201 circuit board.

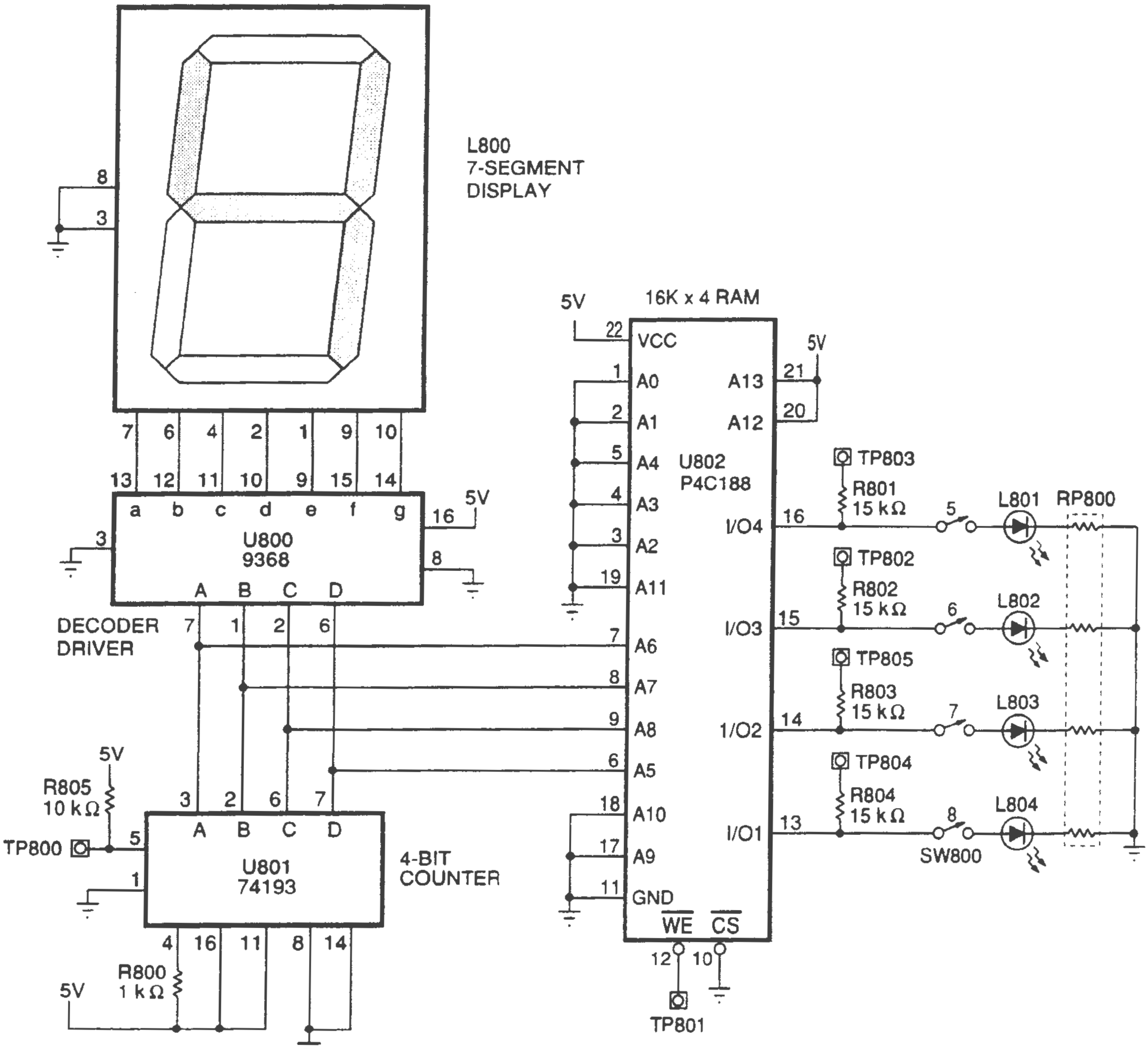


Figure 40-1B
ETB-6201-A circuit board.

8. Which piece of test equipment do you select to start your troubleshooting?

__________________.

9. Why did you choose the test equipment that you listed in step 8?

____.

10. Which is your first choice for a starting test point?

__________________.

11. Did the first test confirm your circuit diagnosis?

__________________.

12. If the cause of the problem is still unknown, list the TP measurements in the order that you will use in determining the exact cause of the circuit's malfunction?

____.

____.

____.

13. What is the exact cause of the problem?

____.

____.

14. What is your proposed corrective action?

____.

____.

15. Perform your recommended corrective action.

16. Is proper circuit operation restored?

____.

17. If you think that the circuit is now operating properly, rerun a complete functional test on the circuit.

18. If you discovered another problem or if the circuit is still malfunctioning, continue your troubleshooting procedures.

19. Once the circuit is operating properly, remove the jumpers, set all switches in block 8 to their low positions and read the summary.

Summary

In this experiment U800 is a 74193 binary counter. When the circuit is wired as shown, L804 should correspond to the LSB. In this case, the value of L804 is the equivalent of a decimal 1.

In normal operation, you should have seen that the 7-segment display is cycling through sixteen steps. This means that the 74193 binary counter, 9368 driver chip, and the 7-segment display are all working properly. The sixteen characters also denote that this is the hexadecimal number system (radix = 16).

However, after you programmed data into RAM, you should have found that the LEDs did not respond to the data you programmed.

A voltage check at pin 18 of the RAM chip reveals that 5 volts is missing. A careful check of the foil path between pin 18 and the 5 volt supply reveals that the supply voltage is applied through dip switch 3. Switch 3 is open and when closed, restores 5 volts to the RAM chip.

A functional check of the circuit now reveals that the data stored in memory is repeated each time that step is repeated. The 7 segment display shows the steps (0 through F) and the LEDs indicate the binary code from 0000 through 1111 or what ever 4-bit data you programmed.

You could have programmed any 4-bits into any step and it would have been retained as long as power is applied to the circuit.

Since the memory is volatile, an interruption in power probably destroyed the stored data.

In normal operation, the A logic switch sets the step counter which is displayed on the 7-segment display. The B logic switch loads the data programmed by the data switches and displayed by the LEDs. The data switches and the LEDs should not be connected to the RAM chip at the same time.

With dip switches 5, 6, 7, and 8 off, the data programmed may or may not agree with the information displayed by the 7 segment display. This will depend on the data that you programmed. The step counter will step from 0 through F sequentially regardless of the data programmed.

You could have cleared the RAM chip by shifting 0000 into each step. This can be accomplished by setting all data switches low, holding the B(NOT) switch down, and cycling through the 16 steps using the A logic switch.

For you to check for continuity with an ohmmeter, you would have had to shut the trainer off. When you shut the trianer off, you destroyed the stored data. Once the fault was found and eliminated, the data must be reprogrammed into the RAM.

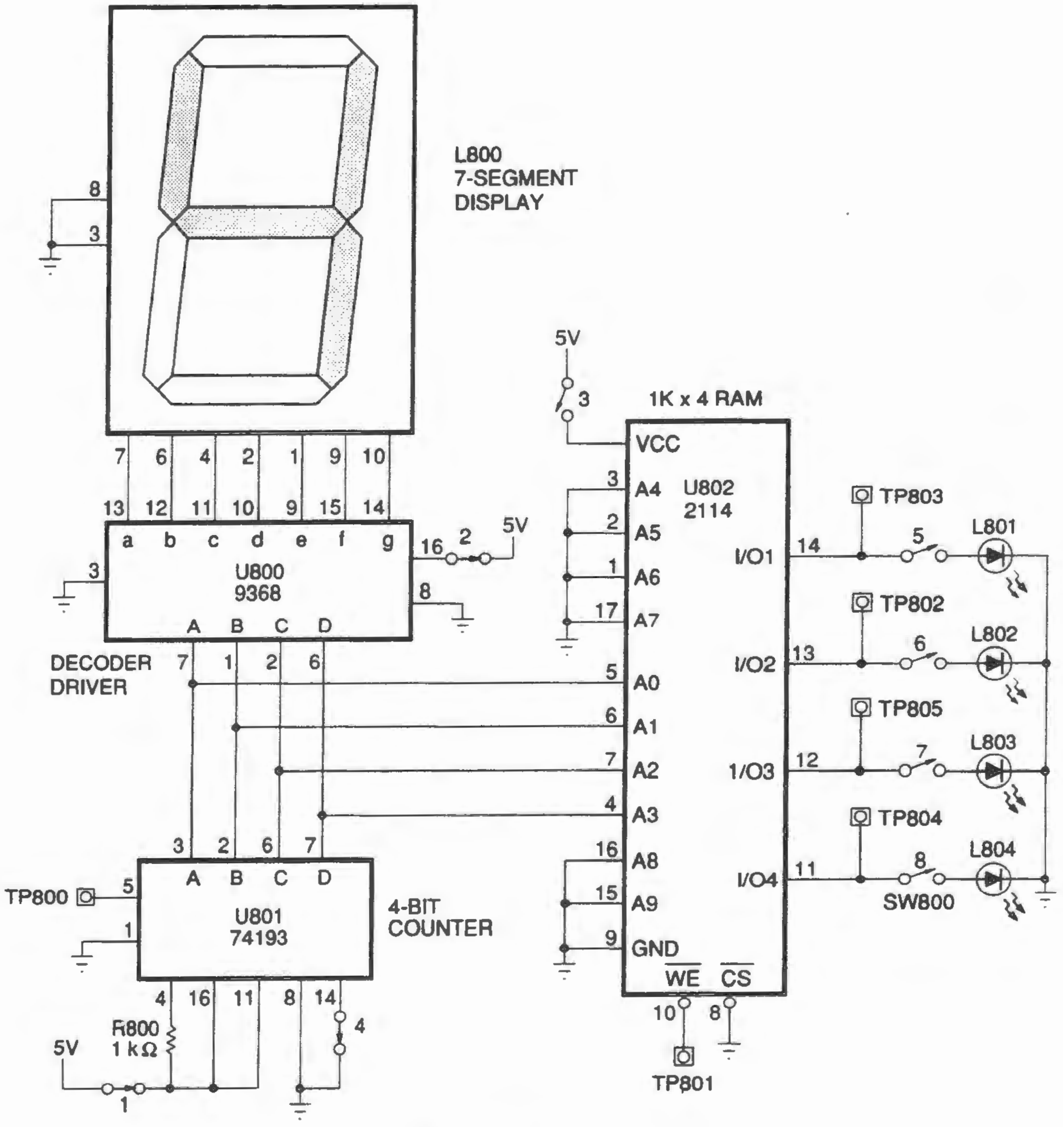


Figure 40-2A
ETB-6201 circuit.

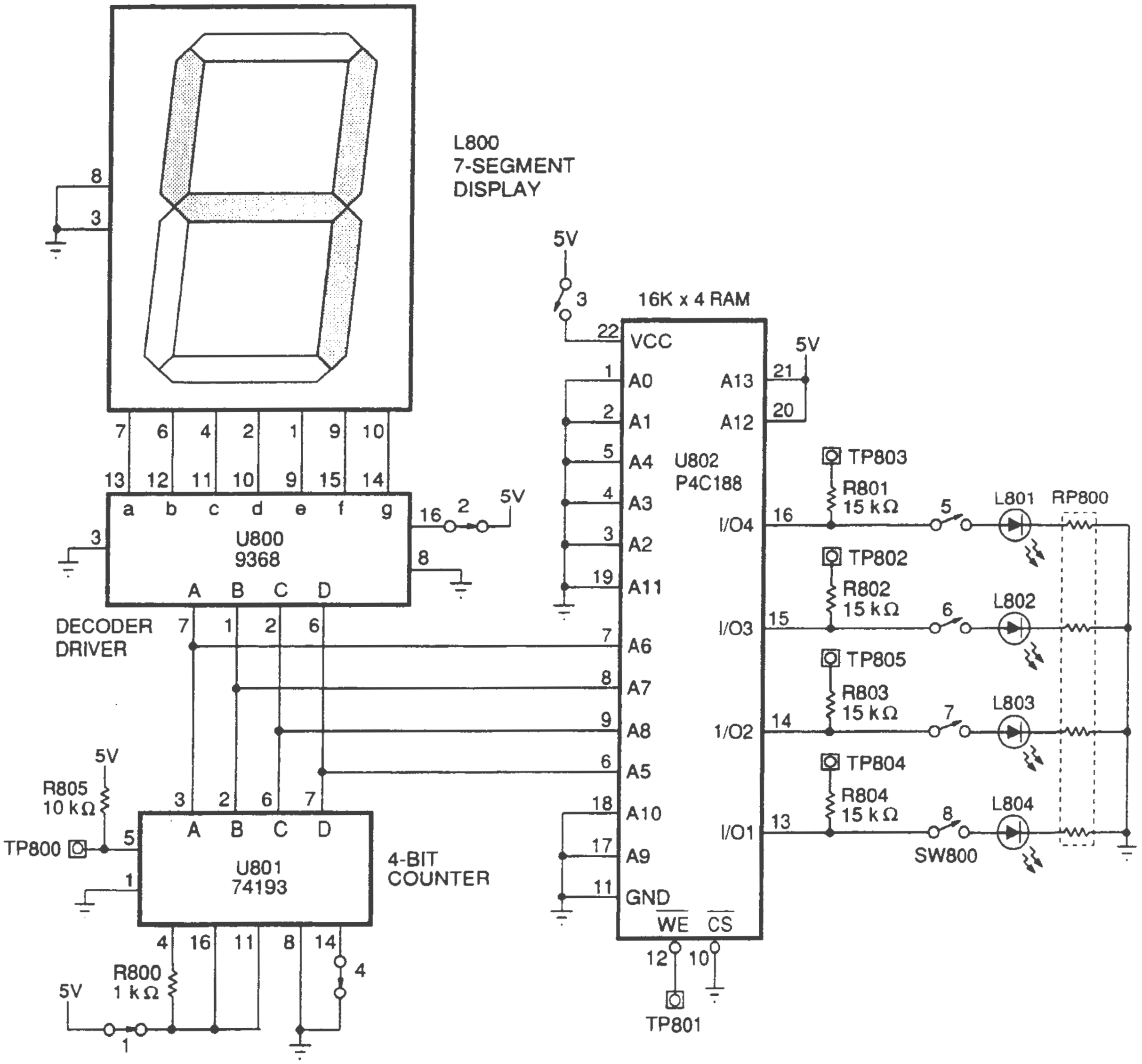


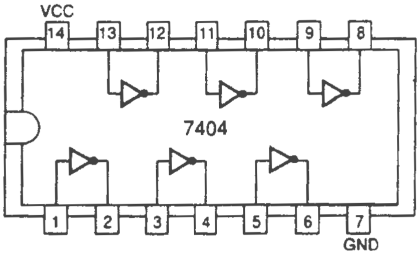
Figure 40-2B

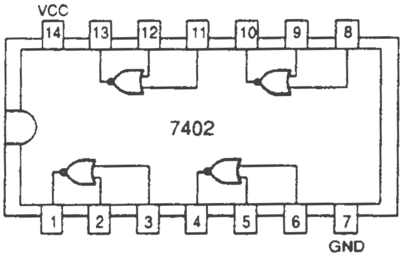
ETB-6201-A circuit.

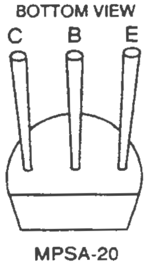
Appendix A

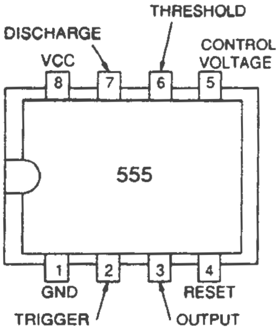
Component Pinout Diagrams

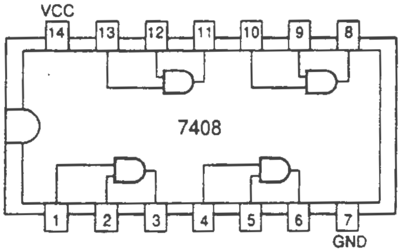
(Top View Of ICs Shown)

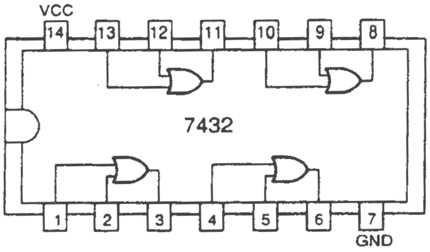


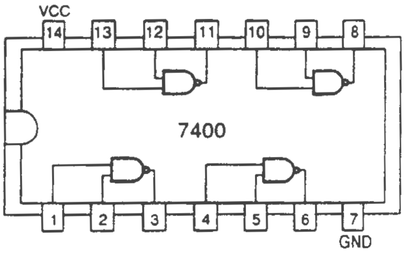


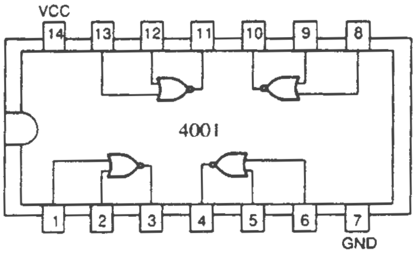


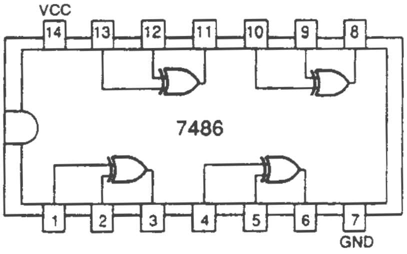


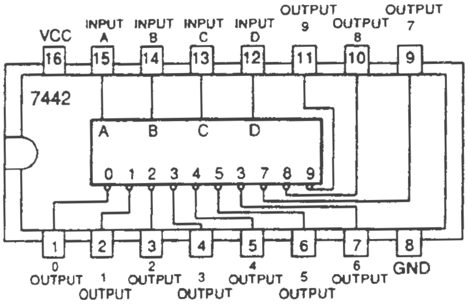


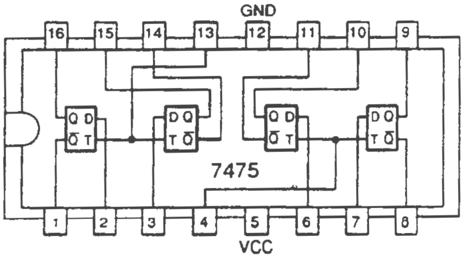


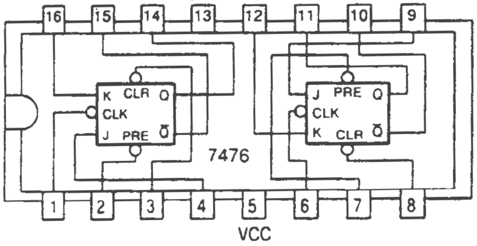


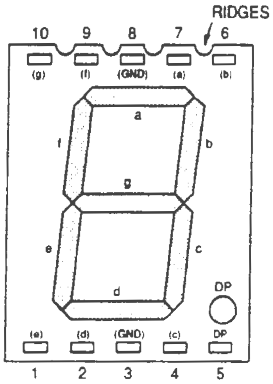


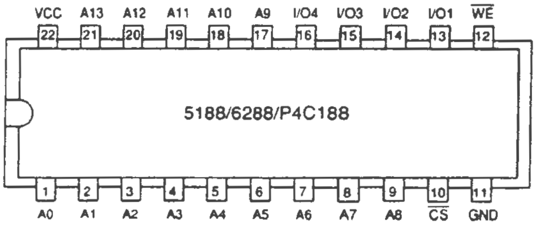


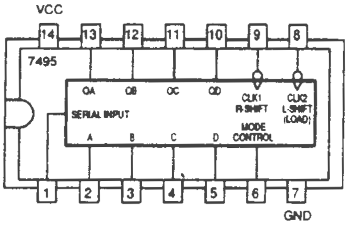


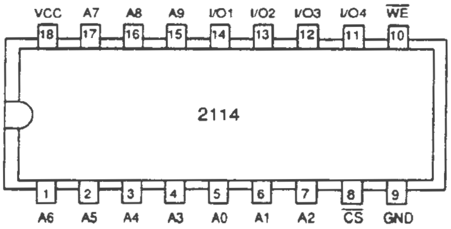


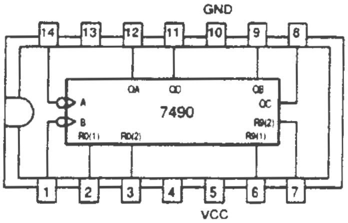


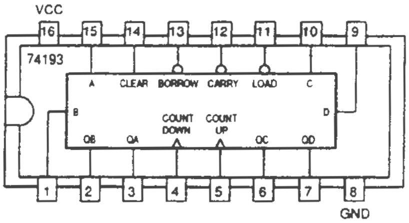



VCC A13 A12 A11 A10 A9 I/O4 I/O3 I/O2 I/O1 WE
22 21 20 19 18 17 16 15 14 13 12
5188/6288/P4C188
1 2 3 4 5 6 7 8 9 10 11
A0 A1 A2 A3 A4 A5 A6 A7 A8 CS GND

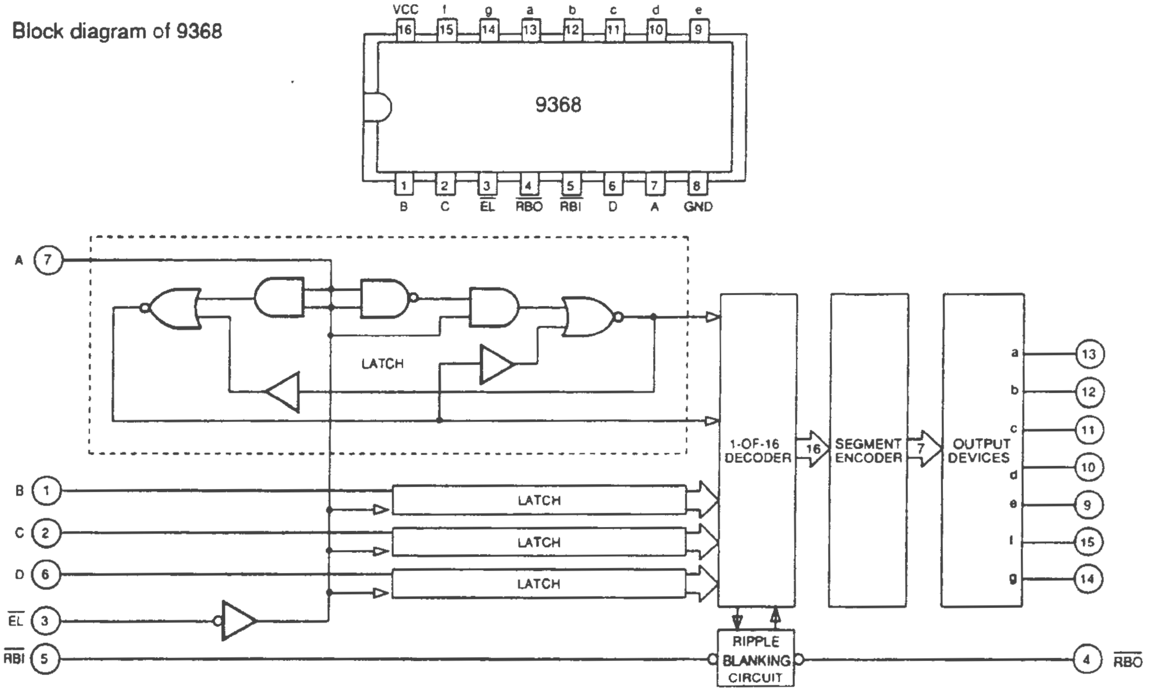



VCC A7 A8 A9 I/O1 I/O2 I/O3 I/O4 WE
18 17 16 15 14 13 12 11 10
2114
1 2 3 4 5 6 7 8 9
A6 A5 A4 A3 A0 A1 A2 CS GND





Block diagram of 9368



Schematic Diagrams

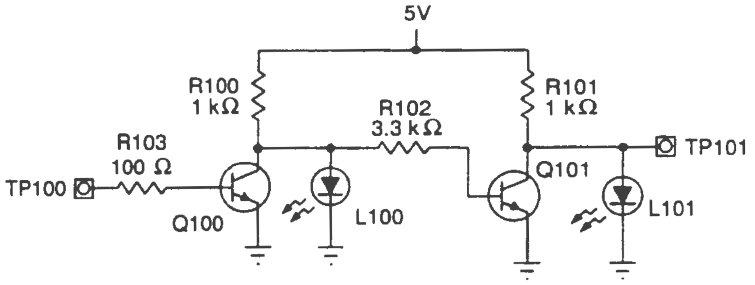


Figure 1-1 Discrete dual inverter.

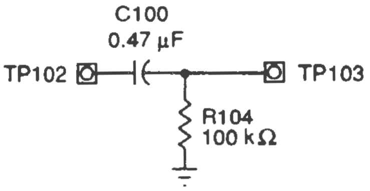


Figure 1-2 RC network.

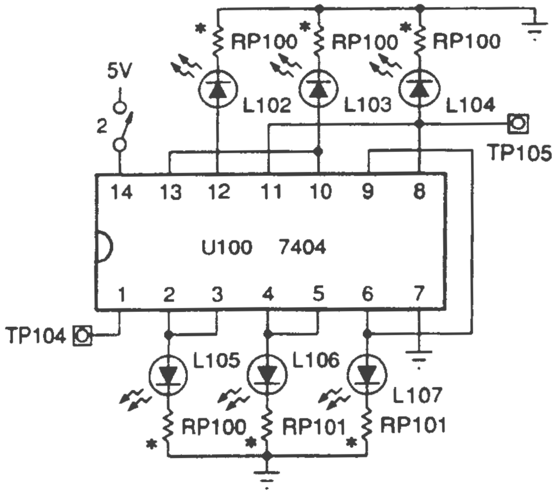


Figure 1-3 Hex inverter.

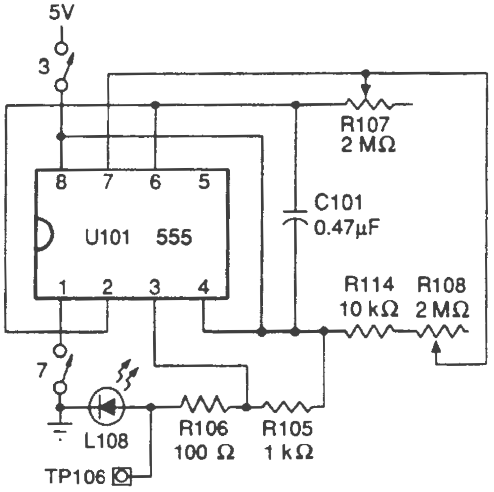


Figure 1-4 Analog clock.

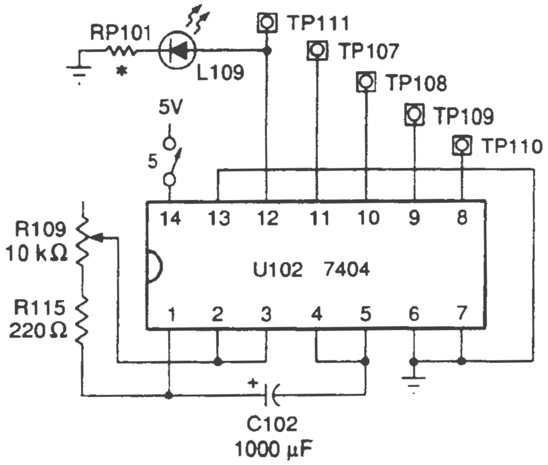


Figure 1-5 Digital clock.

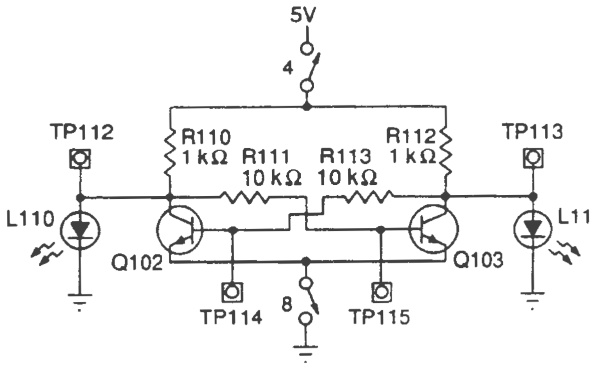


Figure 1-6 Bistable multivibrator.

Block 1

* Resistors installed in ETB-6201-A only.

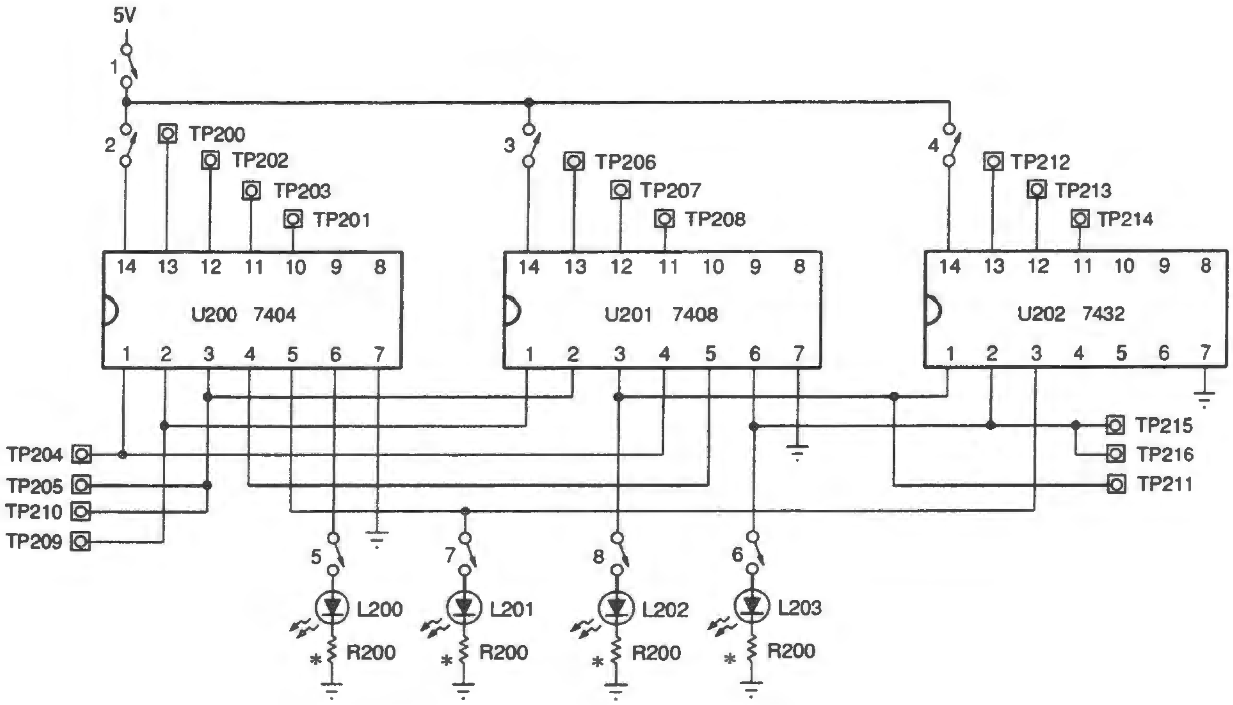


Figure 2-1 Complete Block 200 circuit.

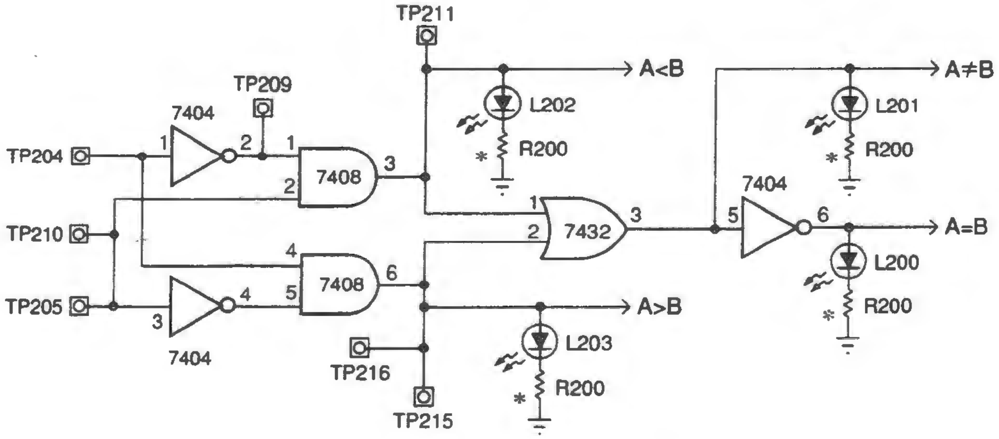


Figure 2-2 Logic circuit.

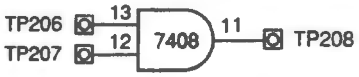


Figure 2-3 AND gate.

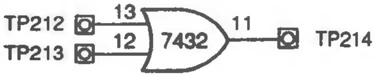


Figure 2-4 OR gate.

* Resistors installed on ETB-6201-A only.

BLOCK 2

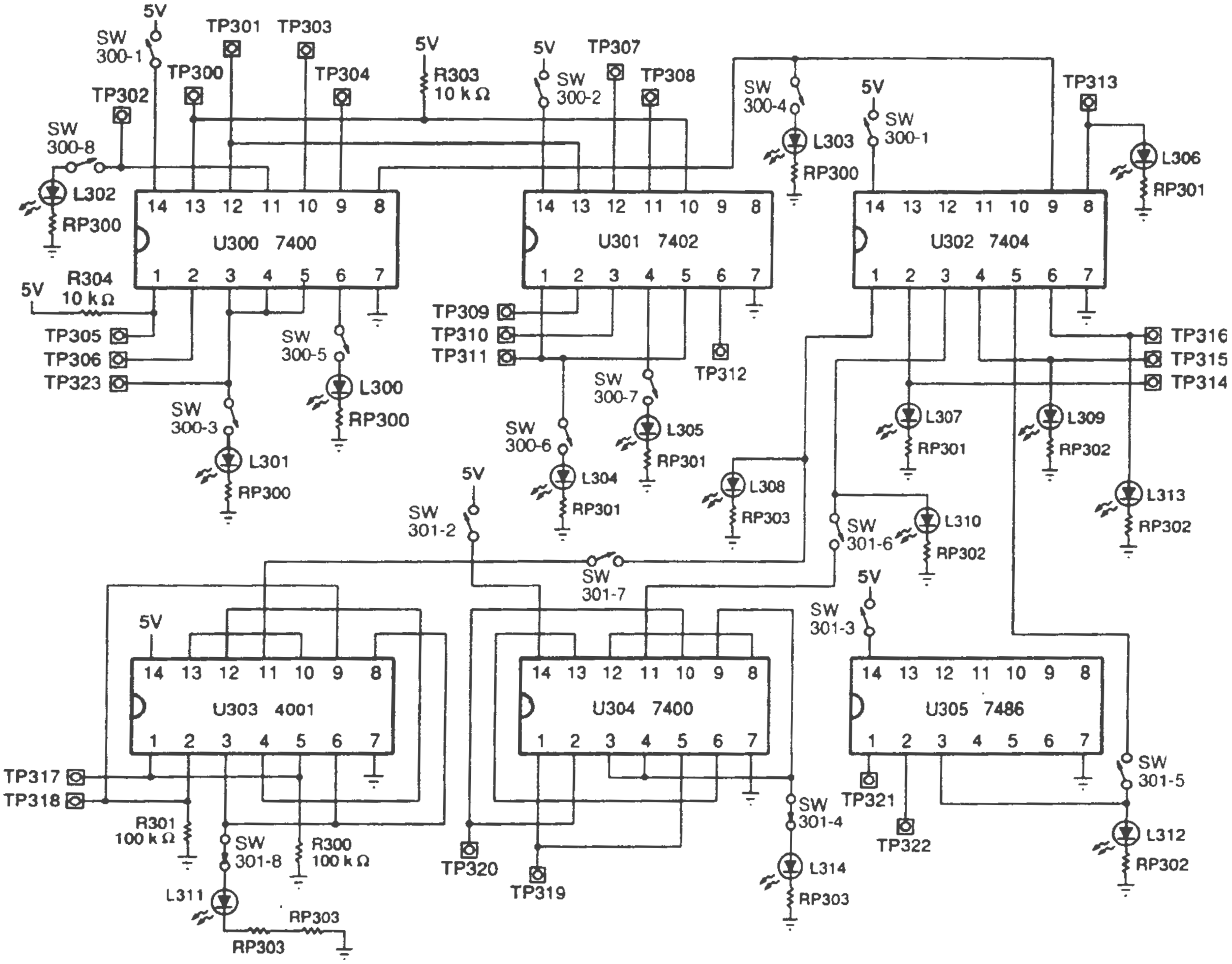


Figure 3-1 Complete Block 300 circuit.

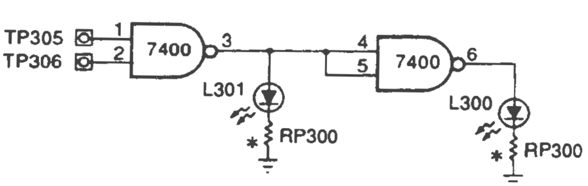


Figure 3-2 NAND to AND circuit.

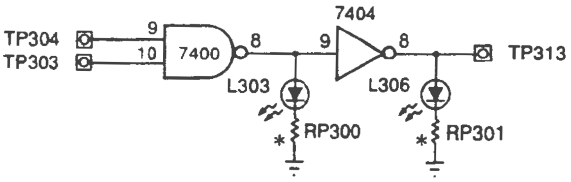


Figure 3-3 NAND to AND circuit.

* Resistors installed on ETB-6201-A only.

BLOCK 3A

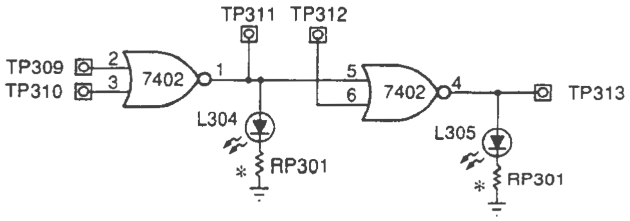


Figure 3-4 NOR to OR circuit.

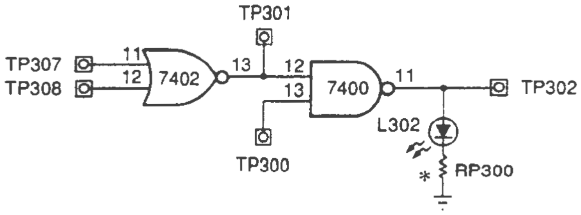


Figure 3-5 NOR to OR circuit.

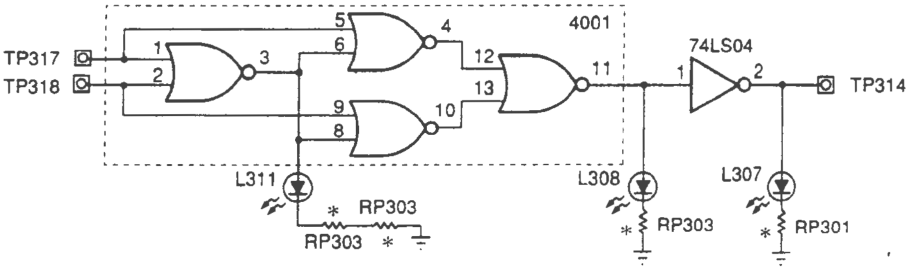


Figure 3-6 Combinational NOR logic circuit.

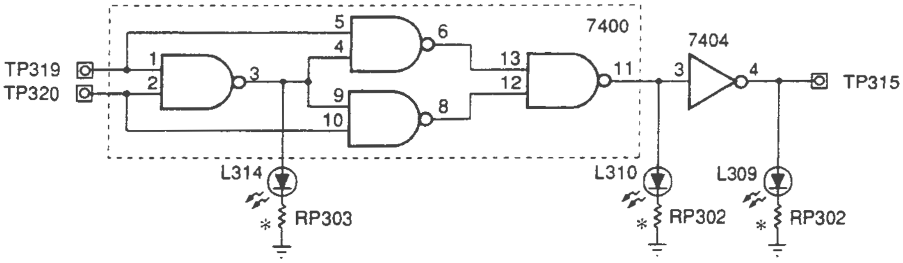


Figure 3-7 Combinational NAND logic circuit.

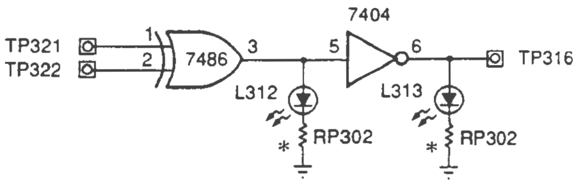


Figure 3-8 EOR to ENOR circuit.

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* Resistors installed on ETB-6201-A only.

BLOCK 3B

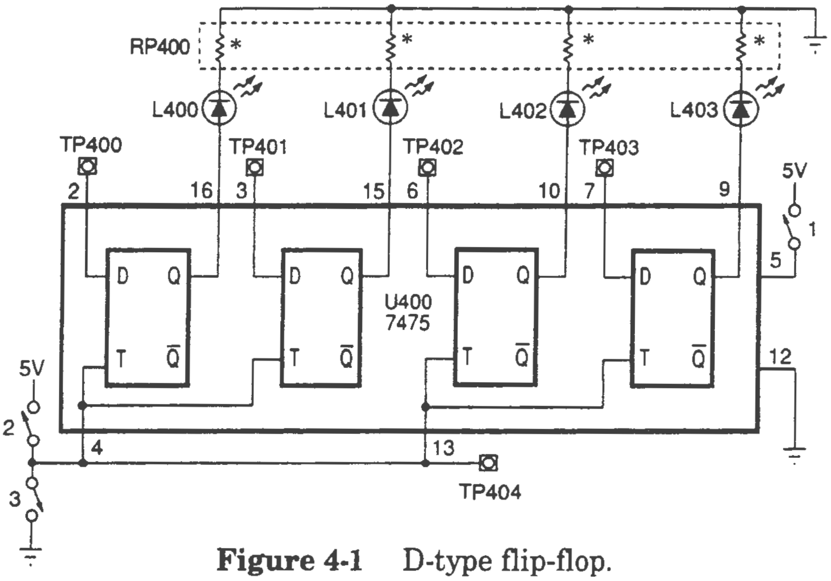


Figure 4-1 D-type flip-flop.

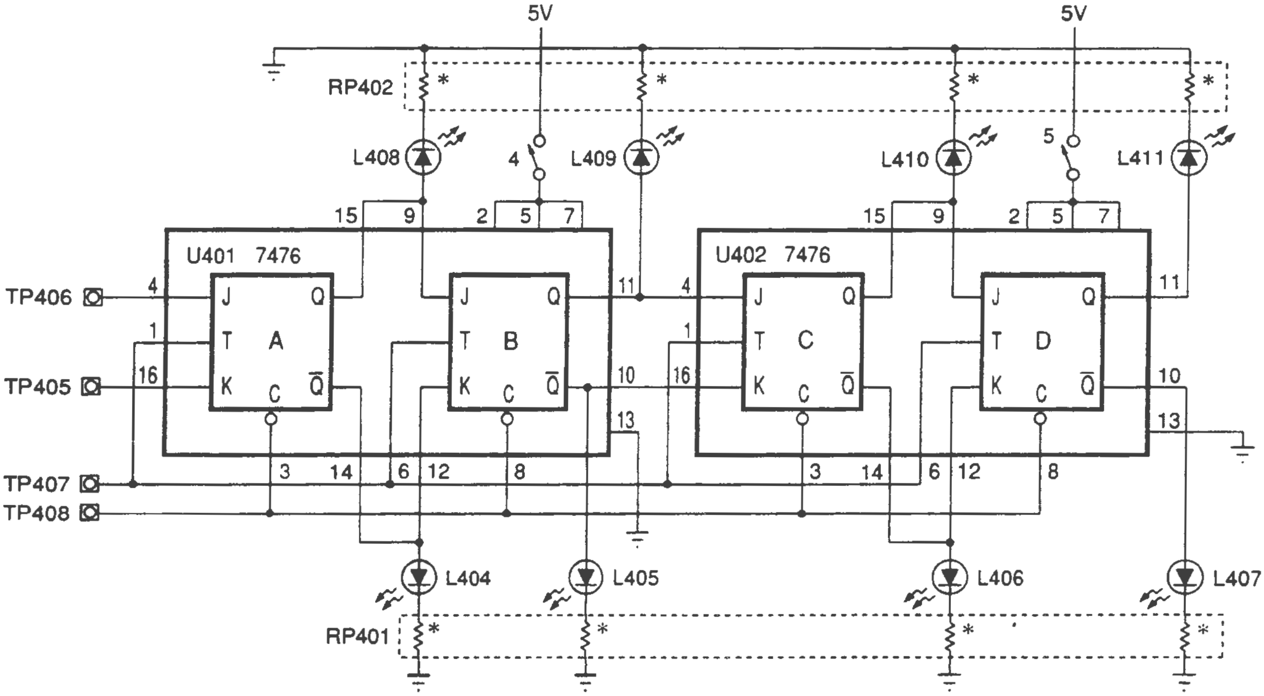


Figure 4-2 Two JK flip-flops.

* Resistors installed on ETB-6201-A only.

BLOCK 4

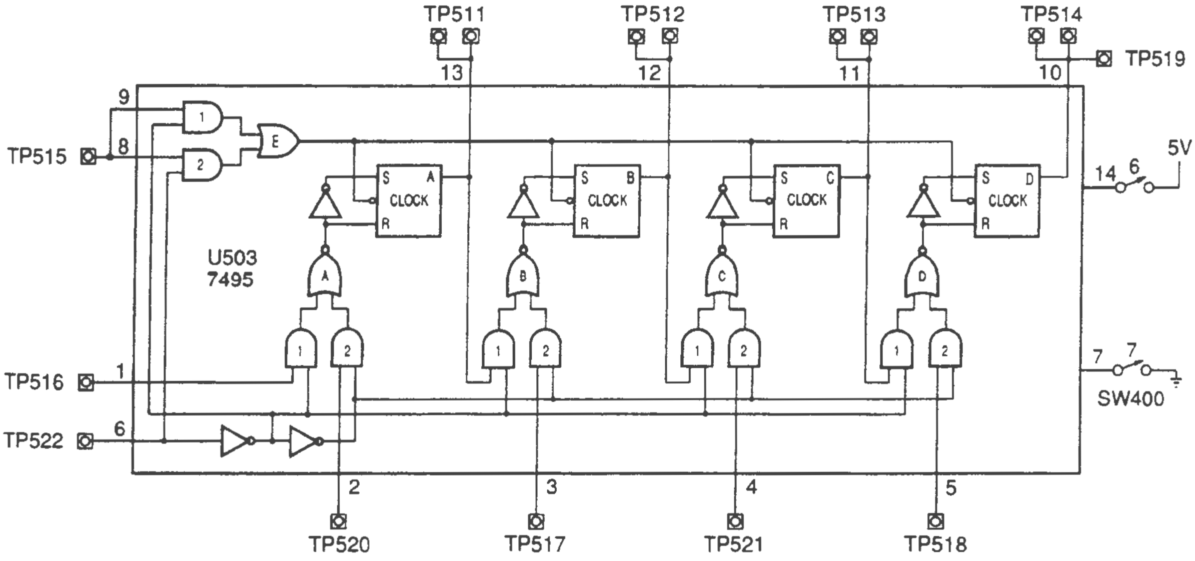
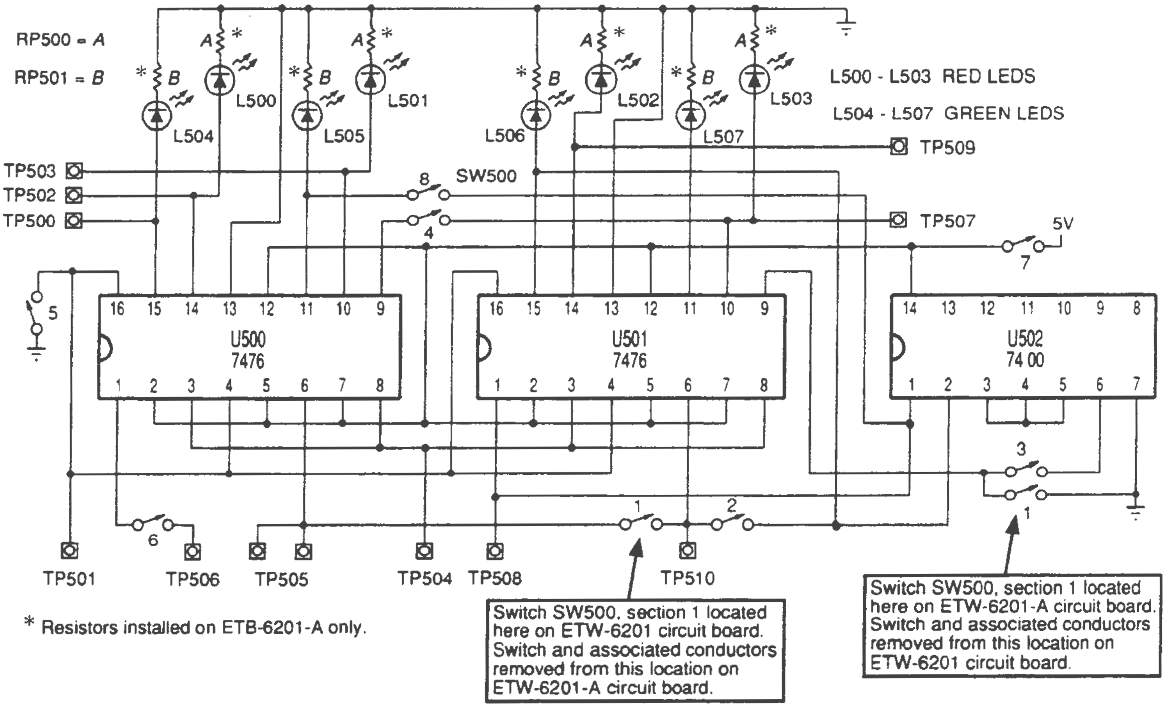


Figure 5-1 Binary Counter.



Switch SW500, section 1 located here on ETW-6201 circuit board. Switch and associated conductors removed from this location on ETW-6201-A circuit board.

Switch SW500, section 1 located here on ETW-6201-A circuit board. Switch and associated conductors removed from this location on ETW-6201 circuit board.

Figure 5-2 JK Counter.

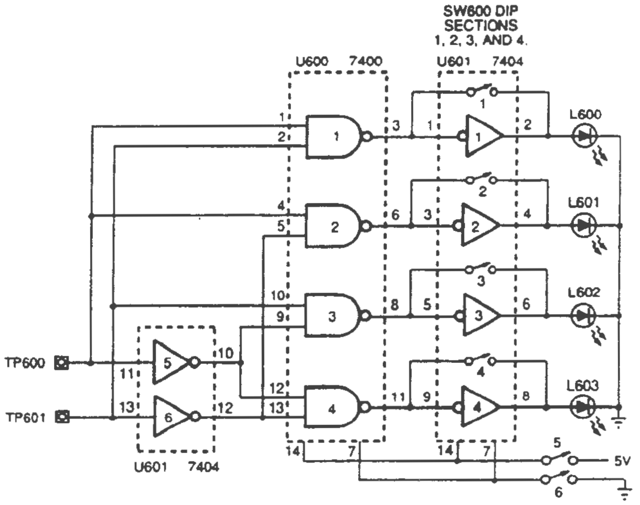


Figure 6-1A One-of-four decoder on ETB-6201 circuit board.

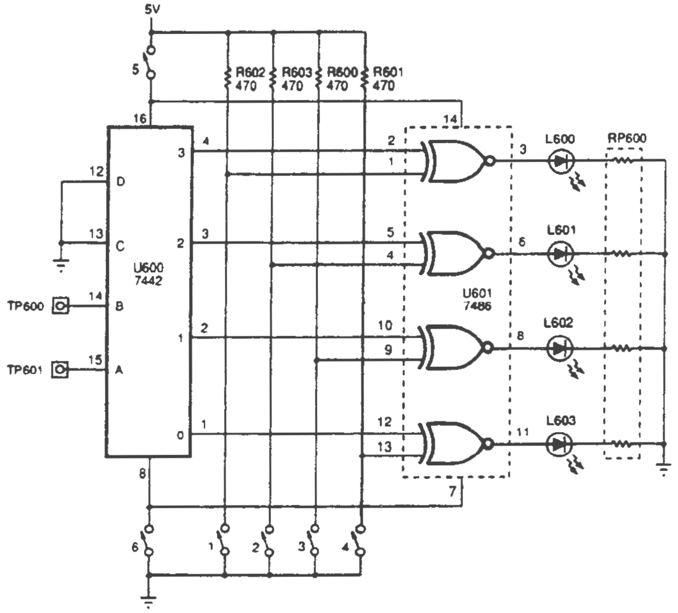
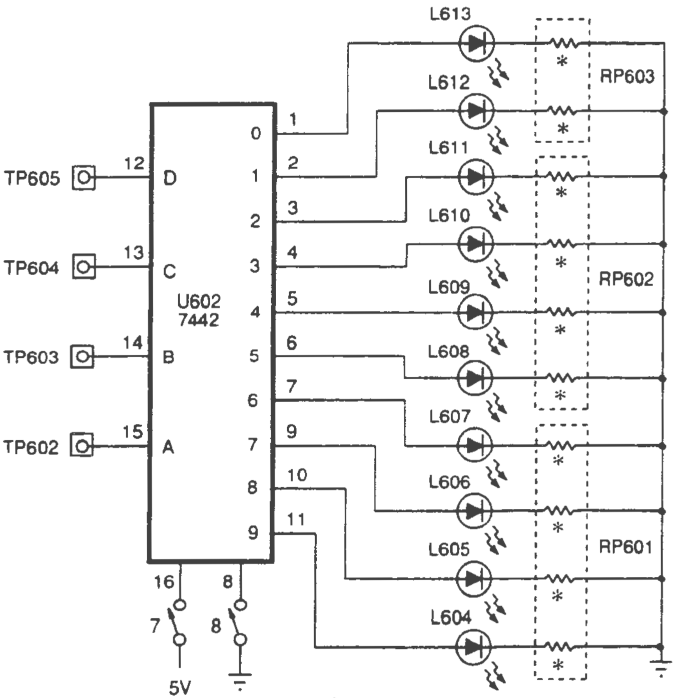


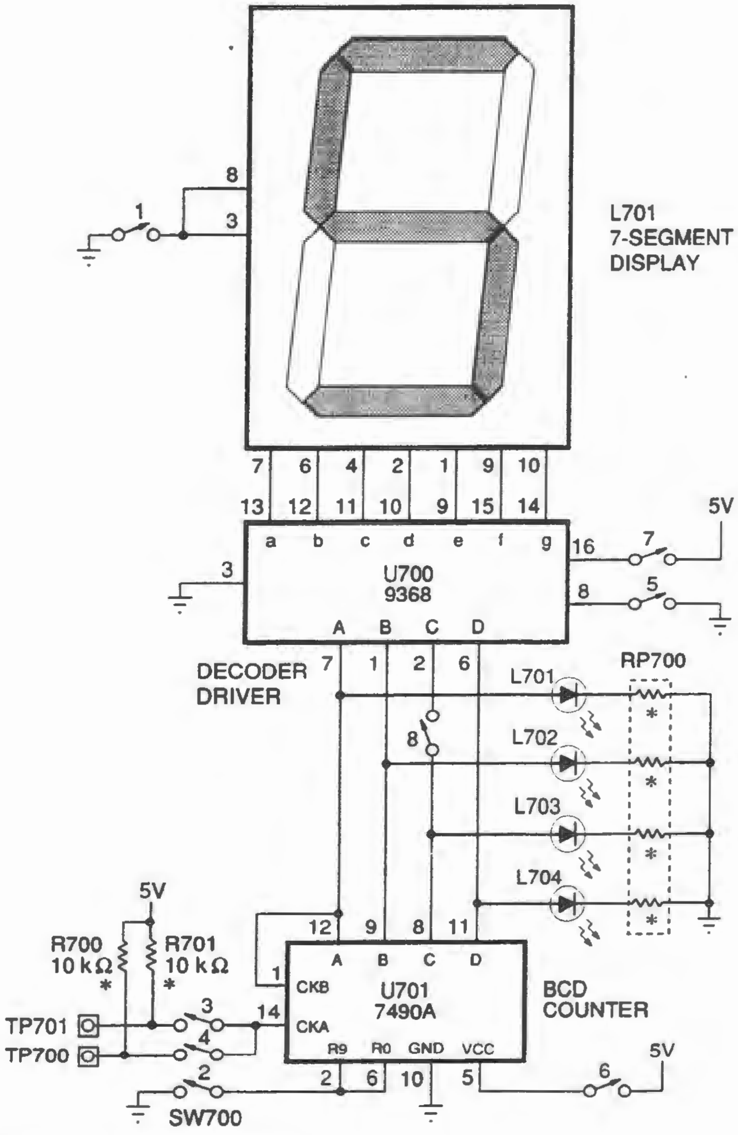
Figure 6-1B One-of-four decoder on ETB-6201-A circuit board.



* Resistors installed on ETB-6201-A only.

Figure 6-2 One-of-ten decoder.

BLOCK 6



* Resistors installed on ETB-6201-A only.

Figure 7-1 BCD Counter.

BLOCK 7

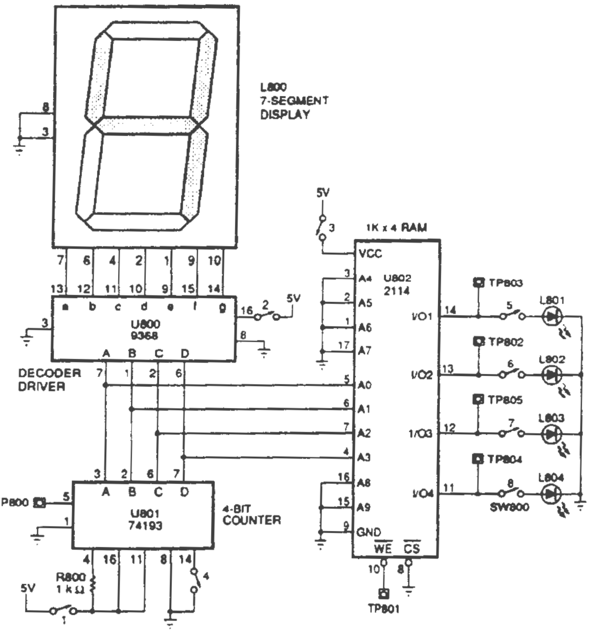


Figure 8-1A ETB-6201 memory programmed RAM circuit.

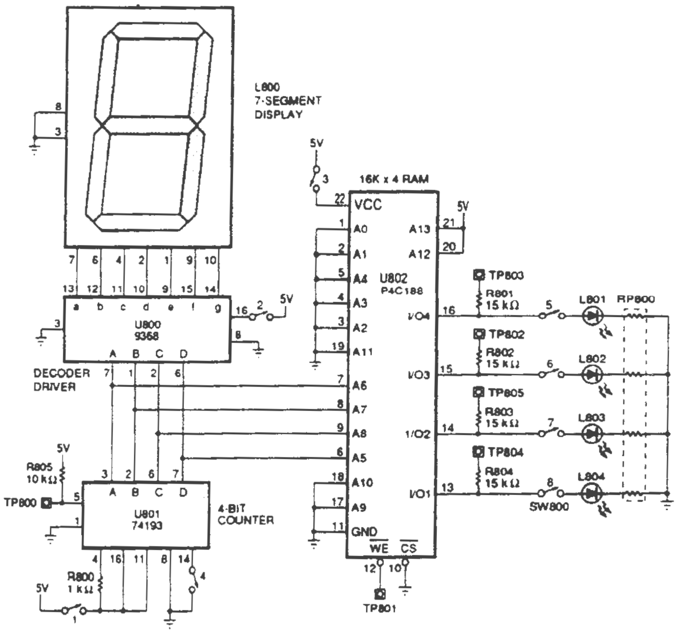
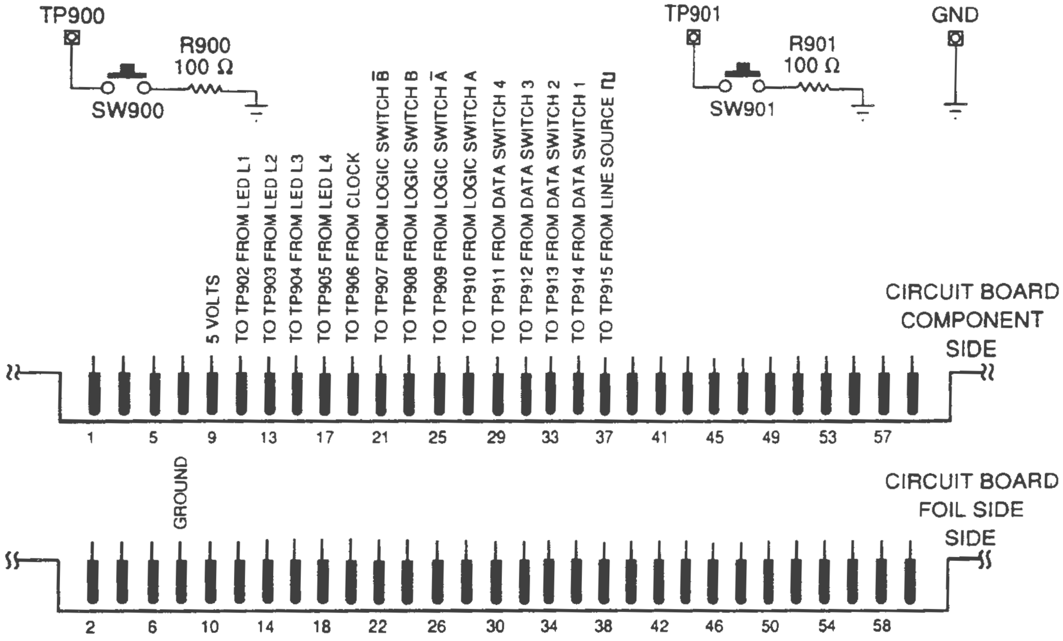


Figure 8-1B ETB-6201-A memory programmed RAM circuit.

BLOCK 8


TP900
R900
100 Ω
SW900
TP901
R901
100 Ω
SW901
GND
5 VOLTS
TO TP902 FROM LED L1
TO TP903 FROM LED L2
TO TP904 FROM LED L3
TO TP905 FROM LED L4
TO TP906 FROM CLOCK
TO TP907 FROM LOGIC SWITCH B̄
TO TP908 FROM LOGIC SWITCH B
TO TP909 FROM LOGIC SWITCH Ā
TO TP910 FROM LOGIC SWITCH A
TO TP911 FROM DATA SWITCH 4
TO TP912 FROM DATA SWITCH 3
TO TP913 FROM DATA SWITCH 2
TO TP914 FROM DATA SWITCH 1
TO TP915 FROM LINE SOURCE
CIRCUIT BOARD COMPONENT SIDE
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
GROUND
CIRCUIT BOARD FOIL SIDE SIDE
2
6
10
14
18
22
26
30
34
38
42
46
50
54
58

CIRCUIT BOARD EDGE CONNECTOR

BLOCK 9

Unit Examinations

Unit 1 Examination

1. Which of the items below is a pure digital device?

   A. auto gasoline gauge.
   B. stepladder.
   C. light bulb.
   D. radio dial.

2. Which of the following is **not** an advantage of digital-over-analog methods?

   A. automation.
   B. lower cost interfaces.
   C. design simplicity.
   D. increased resolution.

3. Which of the following is **NOT** a digital device?

   A. on/off switch.
   B. transistor operating in the linear region.
   C. microprocessor.
   D. RAM and ROM.

4. Select the most correct statement concerning digital devices.

   A. A digital device has a continuously varying output.
   B. Digital devices are always more accurate than analog devices.
   C. Analog outputs can usually be interpreted more accurately than digital devices.
   D. Most digital device outputs represent only two values.

5. The increased use of digital techniques resulted primarily from:

   A. military electronic needs.
   B. the desire to reduce costs.
   C. the development of integrated circuits.
   D. limitations of analog methods.

6. The largest number that a 8-bit binary number can represent is:

   A. 255.
   B. 256.
   C. 128.
   D. 127.

7. The decimal number 23 converts to the binary number?

   A. 10011.
   B. 10111.
   C. 11101.
   D. 11001.

8. How many binary bits does it take to represent the decimal number 1156?

   A. 10.
   B. 11.
   C. 12.
   D. 13.

9. Pick the most correct statement from the list below.

   A. logic gates for storage.
   B. Flip-Flops for decision making.
   C. Gates for decision making and flip-flops for storage.
   D. Gates and flip-flops for both storage and decision making.

10. In BCD, the code 1011 is:

    A. 11.
    B. letter B.
    C. 23.
    D. invalid.

Unit 2 Examination

1. A bipolar transistor acts as a closed switch when it is:

   A. cut-off.
   B. saturated.
   C. amplifying.
   D. reverse-biased.

2. The transistor amplifies if it is operating in which of the following bias regions?

   A. cut-off.
   B. saturation.
   C. linear.
   D. forward-biased.

3. No current flows in a transistor when it is:

   A. cut-off.
   B. saturated.
   C. amplifying.
   D. forward-biased.

4. A transistor, when used in switching or in logic applications, acts like a(n):

   A. amplifier.
   B. oscillator.
   C. variable resistor.
   D. switch.

5. The circuit whose binary output is opposite of its input is called a(n):

   A. amplifier.
   B. inverter.
   C. converter.
   D. switch.

6. A transistor is biased such that its emitter-base junction is forward-biased and its base-collector junction is reversed-biased. The transistor is operating in which region?

   A. linear.
   B. cut-off.
   C. saturation.
   D. The transistor will not operate with this type bias.

7. When both emitter-base and base-collector junctions on a transistor are forward-biased, the transistor is operating in which region?

   A. linear.
   B. cut-off.
   C. saturation.
   D. PIV.

8. Bipolar transistors are generally divided into 2 types, they are the:

   A. enhancement and depletion.
   B. MOS and CMOS.
   C. NPN and PNP.
   D. JFET and IGFET.

9. The term V_{BE} refers to:

   A. voltage drop across the transistor's junctions.
   B. difference of potential referenced from base to emitter.
   C. difference of potential referenced from emitter to base.
   D. either .7 volts for germanium or .3 volts for silicon transistors.

10. Refer to Figure 1. With the bias voltages shown, the transistor is operating in which region?

   A. linear.
   B. cut-off.
   C. saturation.
   D. class A.

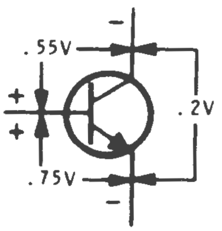


FIGURE 1

11. The MOSFET operating in the enhancement mode has a:

    A. high input impedance and the input appears capacitive.
    B. high input impedance and the input appears reisitive.
    C. low input impedance and the input appears capacitive.
    D. low input impedance and the input appears resistive.

12. Which of the following is **not** a reason why MOSFETs are preferred over bipolar transistors in integrated circuits?

    A. They are smaller.
    B. They consume less power.
    C. They are faster.
    D. They are simpler.

13. An N-channel MOSFET with a threshold of +1.5 volts is not conducting. Which of the following source gate voltages is applied?

    A. +.7 volt.
    B. + 2 volts.
    C. +10 volts.
    D. +15 volts.

14. The factor that most influences the switching speed of a saturated bipolar transistor is:

    A. collector current.
    B. base current.
    C. h_{FE}.
    D. charge storage.

15. You could most improve the switching speed of a bipolar transistor by:

    A. decreasing base current.
    B. increasing collector current.
    C. avoiding saturation.
    D. using a different transistor.

Unit 3 Examination

1. Which of the following is **not** one of the three basic logic elements?

   A. AND.
   B. NAND.
   C. OR.
   D. NOT.

2. In a decision-making logic circuit, where multiple outputs are a function of its multiple inputs and internal circuitry, is called a:

   A. logic element.
   B. logic gate.
   C. sequential circuit.
   D. combinational circuit.

3. A logic circuit featuring flip-flop memory is usually designated as a:

   A. storage element.
   B. storage gate.
   C. sequential circuit.
   D. combinational circuit.

4. To plot all of the possible combinations, for a 4 input logic circuit, would require a truth table containing:

   A. 4 steps.
   B. 8 steps.
   C. 16 steps.
   D. 15 steps.

5. The term discrete logic refers to circuits made up of:

   A. integrated chips.
   B. individual components.
   C. OR, AND, and NOT gates.
   D. diodes only.

6. Analyze the operation of the circuit in Figure 1 using 0 (binary 0) and +5 volt (binary 1) logic levels. The circuit performs with logic function?

   A. NAND.
   B. AND.
   C. OR.
   D. NOR.

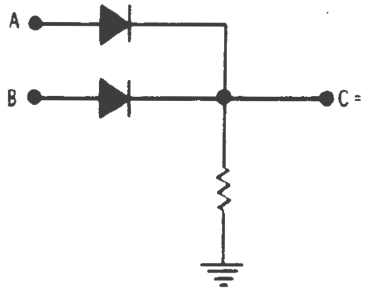


FIGURE 1
Circuit for Unit Exam 3, Question 6.

7. Relay logic circuits are used primarily in applications requiring:

   A. high speeds.
   B. low cost.
   C. small size.
   D. high power.

8. When a complete system is on a single chip it is usually referred to as a/an:

   A. SSI circuit.
   B. MSI circuit.
   C. LSI circuit.
   D. combinational logic circuit.

9. A NAND gate has eight inputs. How many different input combinations are possible?

   A. 8.
   B. 16.
   C. 128.
   D. 256.

10. The circuit in Figure 2 is a positive logic:

   A. OR.
   B. NOR.
   C. AND.
   D. NAND.

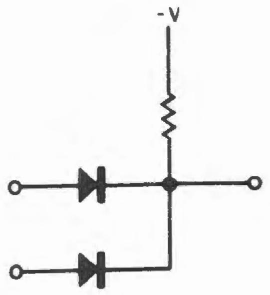


FIGURE 2
Illustration for Question 10 & 11, Unit Exam 3.

11. The circuit in Figure 2 could also be a negative logic:

   A. OR.
   B. NOR.
   C. AND.
   D. NAND.

12. Parallel connected contacts perform the logic function:

   A. AND.
   B. OR.
   C. NAND.
   D. NOR.

13. Series connected contacts perform the logic function:

   A. AND.
   B. OR.
   C. NAND.
   D. NOR.

14. The circuit in Figure 3 performs the positive logic function:

A. OR.
B. NOR.
C. AND.
D. NAND.

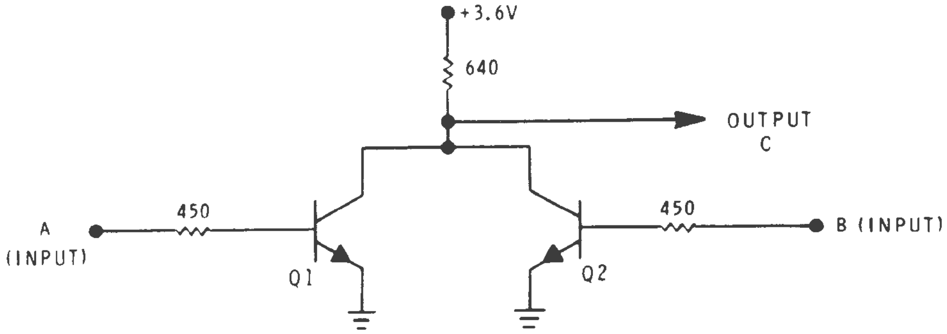


FIGURE 3

Figure for Questions 14, and 15, Unit Exam 3.

15. The circuit in Figure 3 performs the negative logic function:

A. OR.
B. NOR.
C. AND.
D. NAND.

Unit 4 Examination

1. The major class of digital circuits is:

   A. discrete component.
   B. linear.
   C. hybrid.
   D. MOS.

2. The most commonly used digital IC package is the:

   A. T05 can
   B. Flat pack
   C. DIP, plastic
   D. DIP, ceramic

3. Which of the following is **not** a major characteristic of a digital IC?

   A. size.
   B. power consumption.
   C. speed.
   D. noise immunity.

4. The speed of a logic circuit is expressed as:

   A. power consumption.
   B. propagation.
   C. noise immunity.
   D. logic levels.

5. Which of the following use current sinking logic?

   A. MOS.
   B. TTL.
   C. ECL.
   D. CMOS.

6. Which of the following uses current sourcing logic?

   A. MOS.
   B. TTL.
   C. I^2L.
   D. ECL.

7. Which of the following is **not** a bipolar logic circuit?

   A. CMOS.
   B. TTL.
   C. I^2L.
   D. ECL.

8. The fastest digital circuit is:

   A. CMOS.
   B. Schottky TTL.
   C. NMOS.
   D. ECL.

9. The second fastest digital circuit is:

   A. CMOS.
   B. Schottky TTL.
   C. NMOS.
   D. ECL.

10. The digital circuit most desirable for battery operation is:

    A. CMOS.
    B. NMOS.
    C. PMOS.
    D. TTL.

11. The time that it takes a logic circuit to respond to an input and generate an output is called:

    A. speed-power product
    B. power dissipation.
    C. propagation delay.
    D. clock frequency.

12. Which bipolar circuits are non-saturating?

    A. ECL.
    B. standard TTL.
    C. I^2L.
    D. CMOS.

13. Which IC type would be most suitable for noisy industrial applications?

    A. TTL.
    B. ECL.
    C. CMOS.
    D. I^2L.

14. Which digital circuit is best based on a comparison of speed-power products?

    A. 2 picojoules.
    B. 15 picojoules.

15. A multiwire connection between digital circuits is usually called a:

    A. ribbon cable.
    B. bus.
    C. multiplexed line.
    D. wire wrap.

16. The time-sharing of one line with multiple signals is called:

    A. time spacing.
    B. simultaneous transmission.
    C. biderectional.
    D. multiplexing.

17. Time-sharing of multiple lines carrying digital signals is accomplished by using:

    A. three-state TTL.
    B. bistable devices.
    C. disconnect switches.
    D. filters.

18. When a three-state TTL circuit is in its third state, its output looks like a (n):

    A. short circuit.
    B. binary 0.
    C. binary 1.
    D. open circuit.

19. The ability of a logic circuit to reject unwanted signals is expressed as:

    A. noise margin.
    B. propagation delay.
    C. power consumption.
    D. logic levels.

20. The most widely used high speed high power digital circuit is the:

    A. CMOS.
    B. MOS.
    C. TTL.
    D. ECL.

21. The speed of a logic circuit is generally proportional to:

    A. power dissipation.
    B. fan out.
    C. noise immunity.
    D. size.

22. Four TTL gates with an average propagation delay of 5 nanoseconds are cascaded. The propagation delay of the combination in nanosecond is:

    A. 4.
    B. 5.
    C. 9.
    D. 20.

23. A logic gate has a fan out of 8. It is driving three gate inputs. How many more gate inputs can it drive?

    A. 3.
    B. 5.
    C. 11.
    D. 24.

24. The main element in an NMOS logic circuit is a/an:

    A. enhancement mode MOSFET.
    B. depletion mode MOSFET.
    C. saturated bipolar transistor.
    D. Schottky transistor.

25. An IC with 50 gates would be classified as:

    A. SSI.
    B. MSI.
    C. LSI.
    D. VLSI.

Unit 5 Examination

1. The mathematical system used to express, analyze, and design digital circuits is:

   A. the binary number system.
   B. ordinary algebra.
   C. boolean algebra.
   D. canonical maps.

2. The Boolean equation for the circuit in Figure 1 is:

   A. $W = \overline{X}\overline{Y}Z + X\overline{Y}\overline{Z} + XY\overline{Z}$.
   B. $W = XY\overline{Z} + \overline{X}YZ + \overline{X}\overline{Y}Z$.
   C. $W = X\overline{Y}\overline{Z} + \overline{X}YZ + \overline{X}\overline{Y}Z$.
   D. $W = XYZ + \overline{X}YZ + \overline{X}YZ$.

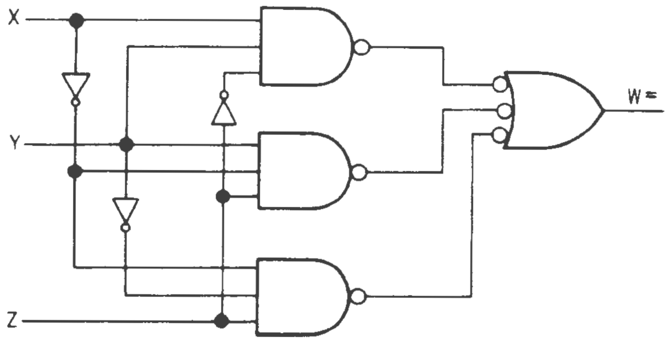


FIGURE 1
Illustration for Question 2, Unit Exam 5.

3. In Boolean algebra a variable:

   A. must be equal to one and its **NOT** function equal to 0.
   B. can be equal to one or zero.
   C. must appear in a sum-of-products form.
   D. must appear in a product-of-sums form.

4. Boolean Algebra is the designer's tool for reducing:

   A. circuit size.
   B. circuit cost.
   C. power consumption.
   D. all of the above are true.

5. The equation $\overline{A\,\overline{C} + \overline{A}\,\overline{B}}$ when minimized becomes:

   A. $A\,C + \overline{A}\,B + \overline{B}\,C$.
   B. $\overline{A}\,C + A\,\overline{B}$.
   C. $A\,C + \overline{A}\,B$.
   D. $A\,C + \overline{A}\,B + B\,C$.

6. The Boolean equation corresponding to the truth table below is:

   A. $W = X\,Y\,\overline{Z} + X\,\overline{Y}\,\overline{Z} + \overline{X}\,\overline{Y}\,Z$.
   B. $W = \overline{X}\,\overline{Y}\,\overline{Z} + \overline{X}\,Y\,\overline{Z} + X\,\overline{Y}\,\overline{Z} + X\,\overline{Y}\,Z + X\,Y\,\overline{Z}$.
   C. $W = \overline{X}\,Y\,Z + \overline{X}\,\overline{Y}\,Z + X\,Y\,Z$.
   D. $W = \overline{X}\,\overline{Y}\,Z + \overline{X}\,Y\,Z + X\,Y\,\overline{Z}$.

INPUTS			OUTPUT
X	Y	Z	W
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	0

7. The equation $W = \overline{X}\,Y\,\overline{Z} + Y\,Z + X\,\overline{Y} + Y\,\overline{Z}$ when minimized as much as possible by Boolean algebra, becomes:

   A. $W = X + Y$.
   B. $W = \overline{X} + \overline{Y}$.
   C. $W = Y\,\overline{Z} + Y\,Z + X\,\overline{Y}$.
   D. $W = X\,\overline{Y} + \overline{Y}$.

8. Which of the following is a form of DeMorgan's theorem?

A. $\overline{A} + \overline{B} = \overline{A}\,\overline{B}$.
B. $\overline{A}\,\overline{B} = \overline{A + B}$.
C. $\overline{A\,B} = \overline{A + B}$.
D. $A + B = A\,B$.

9. Using Boolean algebra and DeMorgan's theorem, the equation $D = (A + \overline{B})\overline{C} + \overline{A\,C}$ can be minimized to:

A. $A\,\overline{B} + \overline{A}\,\overline{C}$.
B. $\overline{A} + \overline{C}$.
C. $A + B\overline{C}$.
D. $A\,\overline{C} + B\,\overline{C} + \overline{A}$.

10. The Boolean equation of the wired AND circuit in Figure 2 is:

A. $D = \overline{A}BC + A\overline{C} + B$.
B. $D = (\overline{A}BC) + (A\overline{C}) + (B)$.
C. $D = \overline{(A\,\overline{C})\,(\overline{A}BC)\,\overline{B}}$.
D. $D = (\overline{A\overline{C}})\,(\overline{\overline{A}BC})\,(B)$.

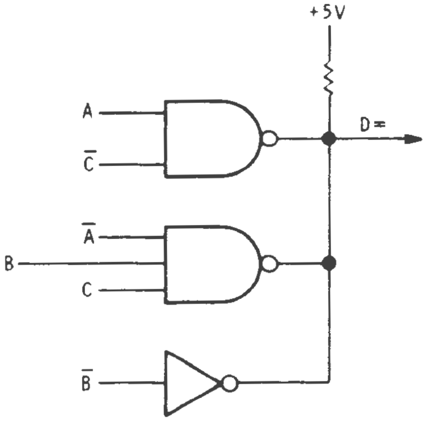


FIGURE 2
Illustration for Question 10, Unit Exam 5.

Unit 6 Examination

1. A flip-flop is a logic element that:

   A. makes decisions.
   B. stores binary data.
   C. generates a clock signal.
   D. buffers NAND gates.

2. Which of the following is **not** a type of flip-flop?

   A. RS.
   B. JK.
   C. register.
   D. D.

3. The normal output of a flip-flop is low. What state is the flip-flop in?

   A. set.
   B. reset.

4. A JK flip-flop toggles:

   A. on the positive or leading edge of the clock pulse.
   B. when the clock switches from binary 0 to binary 1.
   C. when the J and K inputs simultaneously switch from binary 1 to binary 0.
   D. on the negative or trailing edge of the clock pulse.

5. A storage register made up of six D flip-flops is storing a binary word. The flip-flop states are: A = set, B = set, C = reset, D = set, E = reset, F = set. The A flip-flop is the LSB. The decimal equivalent of the register content is:

   A. 43.
   B. 47.
   C. 54.
   D. 59.

6. The outputs of an RS flip-flop when it is in the set condition are:

   A. ones.
   B. zeros.
   C. complementary.
   D. ambiguous.

7. The "limbo" state of a flip-flop is recognizable when:

   A. both outputs are binary 0.
   B. both outputs are binary 1.
   C. both outputs are the same.
   D. the outputs are complementary.

8. A digital circuit used to store a binary number is called a:

   A. flip-flop.
   B. memory.
   C. word.
   D. register.

9. The name given to the class of logic circuits containing flip-flops is:

   A. combinational.
   B. sequential.
   C. linear.
   D. feedback.

10. To reset a positive NOR latch which of the following conditions must occur?

    A. binary 0 to S input
    B. binary 1 to S input
    C. binary 0 to R input
    D. binary 1 to R input

11. To preset a JK flip-flop to the binary 1 state, which of the following conditions must occur?

    A. $J = 1, K = 0$
    B. $S = 0, C = 1$
    C. $J = 0, K = 1$
    D. $S = 1, C = 0$

12. Which of the following is the most common JK flip-flop configuration?

    A. ground the C input.
    B. ground the S input.
    C. set J to 0 and K to 1 and apply a clock pulse.
    D. toggle the T input with J = K = 1.

13. The most common application of the RS flip-flop is:

    A. switch contact debouncing.
    B. registers.
    C. frequency division.
    D. counting.

14. To inhibit a JK flip-flop from toggling, which of the following must occur?

    A. J = 0, K = 1
    B. J = 1, K = 0
    C. J = K = 0
    D. J = K = 1

15. D flip-flops are most frequently used in:

    A. switch contact debouncing.
    B. storage registers.
    C. frequency dividing.
    D. counting.

Unit 7 Examination

1. Which of the following is **not** a sequential logic circuit?

   A. counter.
   B. register.
   C. NOR gate.
   D. one shot.

2. A binary up counter with flip-flops FEDCBA (A = LSB) is preset to the 001101 state. After a number of input pulses are applied, the new counter state is 100011. How many pulses occurred?

   A. 13.
   B. 22.
   C. 26.
   D. 35.

3. A binary counter with 8 flip-flops has a maximum counter capability of:

   A. 8.
   B. 63.
   C. 127.
   D. 255.

4. A binary counter with 12 flip-flops will divide an input by:

   A. 12.
   B. 4096.
   C. 8192.
   D. 16384.

5. Another name for a BCD counter is:

   A. decade counter.
   B. binary counter.
   C. frequency divider.
   D. shift register.

6. Which of the following is an invalid code in a BCD counter?

   A. 0101.
   B. 1001.
   C. 1101.
   D. 0001.

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7. How many BCD counters does it take to count to 102557?

   A. 5.
   B. 6.
   C. 12.
   D. 24.

8. Two cascaded BCD counters divided an input frequency by:

   A. 2.
   B. 8.
   C. 100.
   D. 256.

9. The output frequency of the circuit in Figure 1 is:

   A. 120 kHz.
   B. 240 kHz.
   C. 1.2 MHz.
   D. 2.4 MHz.

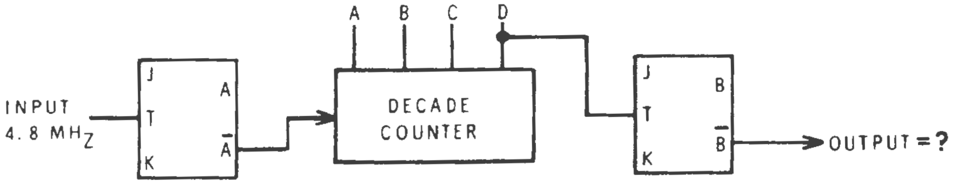

FIGURE 1
Illustration for Question 9, Unit Exam 7.

10. An 8-bit binary up/down counter is initially preset to 10000001. Twenty-seven input pulses increment the counter. Eighty-eight pulses decrement the counter. The binary content is:

    A. 10011100.
    B. 01101001.
    C. 10010110.
    D. 01000100.

11. Clock pulses are applied simultaneous to all flip-flops in which of the following?

    A. synchronous binary counter.
    B. BCD ripple counter.
    C. shift register.
    D. one-shot.

12. How many BCD digits can be stored in an eight-bit shift register?

    A. 1.
    B. 2.
    C. 4.
    D. 8.

13. An 8-bit shift right register contains the number 01011010. A binary 0 is applied to the serial output. After three clock pulses occur, the number in the shift register is:

    A. 11010111.
    B. 00001011.
    C. 11010000.
    D. 11101011.

14. Parallel-to-serial data conversion is normally performed by a:

    A. BCD counter.
    B. binary counter.
    C. shift counter.
    D. shift register.

15. An 8-bit shift register contains the number 00001000. Three clock pulses are applied shifting the word to the left. The operation performed is:

    A. multiplication by 3.
    B. division by 3.
    C. multiplication by 8.
    D. division by 8.

16. The input to a sequential shift register is:

    A. serial.
    B. parallel.
    C. logic 1.
    D. logic 0.

17. Which of the following is **not** a name for the circuit that generates pulses to operate a sequential circuit?

    A. one-shot.
    B. clock.
    C. astable multivibrator.
    D. oscillator.

18. The circuit that can delay an input by a fixed duration each time it is triggered is called a(n):

    A. astable multivibrator.
    B. monostable.
    C. clock.
    D. pulser.

19. Which of the following requires data recirculation and a continuous minimum frequency clock for proper operation?

    A. synchronous counter.
    B. Johnson counter.
    C. TTL shift register.
    D. dynamic MOS shift register.

20. Two phase clocks are usually used with which type logic?

    A. CMOS.
    B. MOS.
    C. ECL.
    D. TTL.

Unit 8 Examination

1. The logic gate shown in Figure 1 is best described as a/an:

   A. AND gate.
   B. NAND gate.
   C. decoder.
   D. multiplexer.

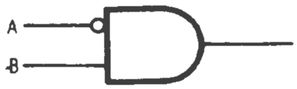

FIGURE 1
Illustration for Question 1, Unit Exam 8.

2. A decoder has inputs $\overline{A}BC\overline{D}\overline{E}F$ where A is the LSB of a number. The number being recognized is:

   A. 011001.
   B. 011000.
   C. 100110.
   D. 110010.

3. A decoder with four inputs can have a maximum of how many outputs?

   A. 4.
   B. 8.
   C. 16.
   D. 32.

4. Which of the following cannot be used as a decoder?

   A. inverter.
   B. NAND.
   C. AND.
   D. NOR.

5. In a multiple output decoder made with NAND gates, which of the following is true?

   A. The selected output will be high.
   B. The selected output will be low.
   C. Only one output will be high.
   D. All outputs will be low.

6. Another name for a data selector is:

   A. decoder.
   B. demultiplexer.
   C. encoder.
   D. multiplexer.

7. Parallel-to-serial data conversion can be performed with which of the following?

   A. demultiplexer.
   B. multiplexer.
   C. clock.
   D. decoder.

8. The input selected by a multiplexer is determined by a multibit input called the:

   A. input code.
   B. output code.
   C. address.
   D. channel number.

9. The multiplexer in Figure 2 (last page of this Exam) has inputs D_0, D_2, D_3, D_5, and D_7 grounded. Inputs D_1, D_4, and D_6 are connected to +5 volts. The sum-of-products Boolean output is:

   A. $\overline{A}\,\overline{B}C + A\overline{B}\,\overline{C} + AB\overline{C}$.
   B. $A\overline{B}C + \overline{A}B\overline{C} + \overline{A}\,\overline{B}C$.
   C. $A\overline{B}C + \overline{A}\,\overline{B}\,\overline{C} + A\overline{B}C$.
   D. $A\overline{B}\,\overline{C} + \overline{A}\,\overline{B}C + \overline{A}BC$.

10. A circuit that generates a specific output code in response to an input is called a(n):

    A. encoder.
    B. decoder.
    C. code converter.
    D. data selector.

11. The Boolean equation for an exclusive OR is:

    A. $\overline{XY} + \overline{X}\overline{Y}$.
    B. $\overline{X}Y + X\overline{Y}$.
    C. $XY + X\overline{Y}$.
    D. $\overline{XY} + \overline{XY}$.

12. A single bit comparator is called a(n):

    A. exclusive OR.
    B. wired OR.
    C. exclusive NOR.
    D. NOR gate.

13. The circuit that detects bit errors in a binary word is called a:

    A. comparator.
    B. exclusive NOR.
    C. decoder.
    D. parity detector.

14. The parity bit added to the word 101011010110 to create even parity is:

    A. 0.
    B. 1.

15. The most common code converter, converts between the:

    A. Gray and BCD codes.
    B. Binary and excess 3 codes.
    C. BCD and binary codes.
    D. Gray and binary codes.

16. The circuit that would change the pure binary code into ASCII is called a(n):

    A. code converter.
    B. decoder.
    C. encoder.
    D. demultiplexer.

17. The input applied to a ROM is called the:

    A. input code.
    B. address.
    C. memory.
    D. micro instruction.

18. How many bytes of data can be stored in a 16384-bit ROM?

    A. 512.
    B. 1024.
    C. 2048.
    D. 4096.

19. An LSI circuit that implements multiple sum-of-products Boolean equations is called a(n):

    A. multiplexer.
    B. ROM.
    C. decoder/demultiplexer.
    D. PLA.

20. The main element of a microprogrammed controller is a(n):

    A. address register.
    B. PLA.
    C. ROM.
    D. binary counter.

21. A ROM has six inputs and eight outputs. How many bits does the ROM store?

    A. 512.
    B. 1536.
    C. 2048.
    D. 4096.

22. A multiplexer is an electronic circuit that has:

    A. a single input and multiple outputs.
    B. multiple inputs and a single output.
    C. two or more inputs and outputs.
    D. analog inputs and digital outputs.

23. Which of the following is **not** a good ROM application?

    A. look-up table.
    B. code conversion.
    C. squaring (X^2).
    D. addition.

24. A combinational logic circuit whose multiple sum-of-product outputs can be programmed by the user is a(n):

    A. multiplexer.
    B. decoder.
    C. PLA.
    D. ROM.

25. Which of the following is **not** an application for an exclusive OR?

    A. code generation.
    B. complementing.
    C. addition.
    D. parity generation.

Unit 9 Examination

1. Which of the following non-semiconductor devices are commonly used in digital memories?

   A. flip-flops.
   B. relays.
   C. vacuum tubes.
   D. magnetic cores.

2. Storing data into a memory is called:

   A. writing.
   B. stashing.
   C. memorizing.
   D. remembering.

3. Retrieving data from a memory is called:

   A. getting.
   B. reading.
   C. fetching.
   D. accessing.

4. A ROM is also a:

   A. serial access memory.
   B. read/write memory.
   C. random access memory.
   D. volatile memory.

5. The basic storage circuit of a sequential access digital memory is a:

   A. counter.
   B. shift register.
   C. capacitor.
   D. one-shot.

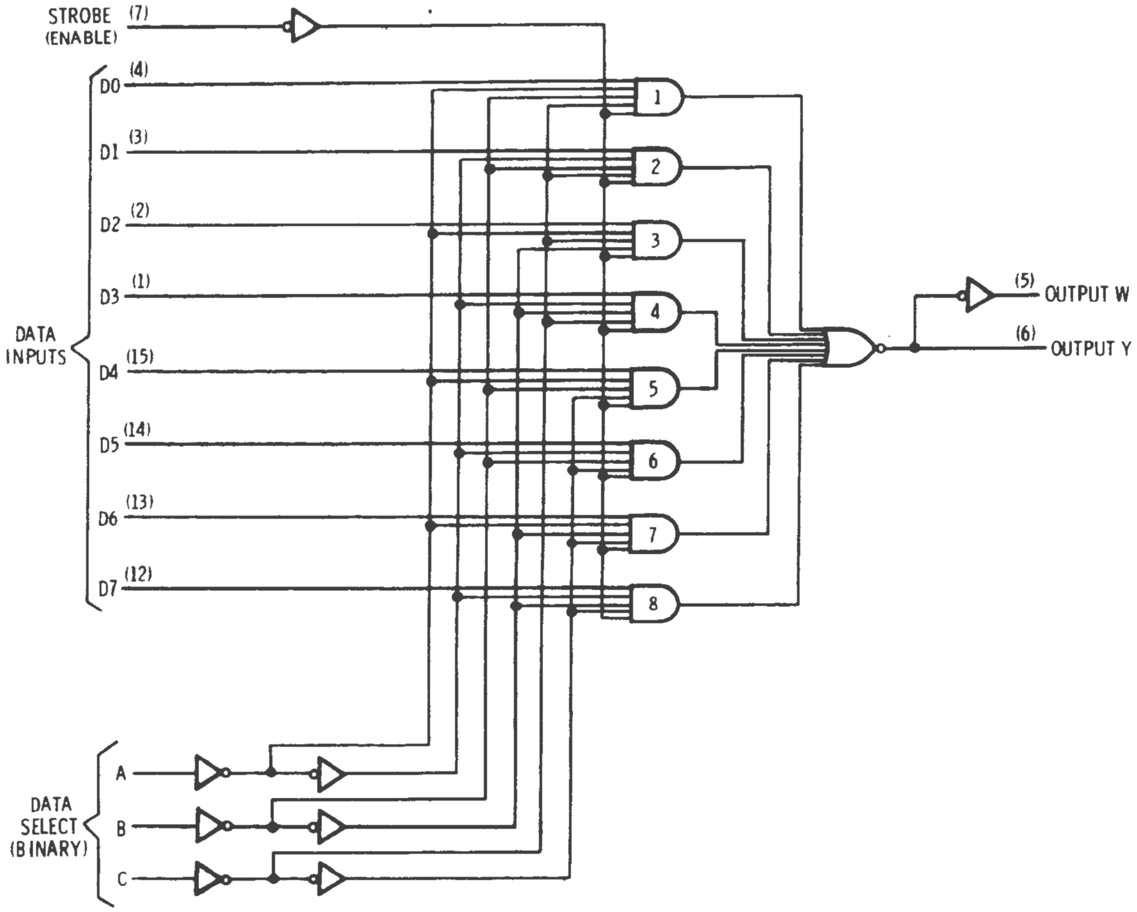

FIGURE 2
Illustration for Question 9, Unit Exam 8.

6. The number given to a memory location for reference purposes is called the:

   A. mantissa.
   B. code.
   C. instruction.
   D. address.

7. To sequentially store 4096 7-bit ASCII words, a shift register must have how many bits?

   A. 16,384.
   B. 28,672.
   C. 32,768.
   D. 65,536.

8. The loss of data from a power failure in a semiconductor memory is called:

   A. volatility.
   B. nonvolatility.
   C. erasure.
   D. nonpermanence.

9. The interval required to address and read out a memory word is called:

   A. access time.
   B. pulse duration.
   C. settling time.
   D. propagation delay.

10. In memory terminology, K means:

    A. 1,000.
    B. 1,024.
    C. 10,000.
    D. 100,000.

11. Which configuration below refers to a memory that can store 32,768 bytes?

    A. 8K × 32.
    B. 32K × 4.
    C. 32K × 8.
    D. 32,768 × 4.

12. How many 16K × 1 memory ICs does it take to form a 128K × 8 memory?

    A. 16.
    B. 32.
    C. 64.
    D. 128.

13. The standard designation for a read/write memory is:

    A. RAM.
    B. ROM.
    C. RWM.
    D. RMM.

14. Which of the following is an advantage of a dynamic RAM over a static RAM?

    A. easier to use.
    B. higher power dissipation.
    C. larger size, greater chip density.
    D. faster.

15. More bits may be stored in a given area with dynamic cells because:

    A. dynamic cells are larger.
    B. dynamic cells are smaller.
    C. dynamic cells consume less power.
    D. dynamic cells are faster.

16. The access time of a static RAM is predominately:

    A. charge/discharge time.
    B. propagation delay.
    C. speed of external circuits.
    D. storage element characteristics.

17. Which of the following is **not** a typical characteristic of a bipolar RAM?

    A. high power consumption.
    B. high speed.
    C. nonvolatility.
    D. small storage capacity.

18. Typical access times for a MOS dynamic RAM are:

    A. 5 – 20 ns.
    B. 20 – 100 ns.
    C. 100 – 500 ns.
    D. 500 – 900 ns.

19. A 64 K × 8 memory can store how many bytes?

    A. 32 K.
    B. 64 K.
    C. 128 K.
    D. 265 K.

20. Which organization is most typical for a PROM?

    A. 4 K × 1.
    B. 4 K × 4.
    C. 4 K × 8.
    D. 4 K × 16.

21. The flip-flop is the main storage element in which kind of memory?

    A. static.
    B. dynamic.
    C. core memory.
    D. capacitive storage.

22. The main storage element in a dynamic memory is a:

    A. flip-flop.
    B. capacitor.
    C. one-shot.
    D. MOSFET.

23. Lowest power consumption is obtained with which type of memory?

    A. ECL.
    B. TTL.
    C. MOS.
    D. flip-flop.

24. The memory IC input that "turns on" the circuitry in preparation for a read or write operation is called the:

    A. address.
    B. read/write.
    C. chip enable.
    D. clear.

25. A memory IC with a 128 × 128 storage matrix can retain how many data bits?

    A. 128.
    B. 16 K.
    C. 64 K.
    D. 128 K.

26. Another name for the read/write control line is:

    A. write enable.
    B. chip select.
    C. address.
    D. shift input.

27. In multi-IC memories, extra decoders enable the selected chips through which IC inputs?

    A. address.
    B. read/write.
    C. data input.
    D. chip select.

28. Restoring the charge on a dynamic storage cell is called:

    A. refresh.
    B. store.
    C. write.
    D. retain.

29. The refresh operation in a typical dynamic RAM takes place every:

    A. 100ns.
    B. 2 μs.
    C. 10 μs.
    D. 2ms.

30. The refresh operation is usually performed by a special IC called a:

    A. binary counter.
    B. dynamic RAM controller.
    C. shift register.
    D. multiplexer.

31. ROMs into which data can be written by user are called:

    A. RAMs.
    B. ROMs.
    C. PROMs.
    D. RWMs.

32. Bipolar PROMs are programmed by:

    A. biasing a bipolar transistor.
    B. blowing a fuse.
    C. masking a bipolar transistor.
    D. charging a floating gate.

33. The main storage element in a MOS PROM is a:

    A. fuse.
    B. MOSFET.
    C. floating gate MOSFET.
    D. bipolar transistor.

34. EPROMs can be erased by:

    A. blowing a fuse.
    B. applying a 21-volt pulse.
    C. turning off the power.
    D. applying ultraviolet light.

35. The device used to store data in a PROM is called a/an:

    A. PROM programmer.
    B. microcomputer.
    C. paper tape reader.
    D. ultraviolet light source.

Unit 10 Examination

1. The increased use of data conversion circuits is the result of the increased application of:

   A. op amps.
   B. digital equipment.
   C. computers.
   D. linear circuits.

2. Which of the following does **NOT** affect the output amplitude of a DAC?

   A. current switch speed.
   B. binary input.
   C. reference voltage.
   D. op amp feedback resistor.

3. The primary disadvantage of a weighted resistor DAC is its:

   A. current switch speed.
   B. binary input.
   C. reference voltage.
   D. op amp feedback resistor.

4. The resolution of a 9-bit DAC is:

   A. .001953%.
   B. .1953%.
   C. 195.3 ppm.
   D. 1953 ppm.

5. Which set of resistor values could be used in an R/2R DAC?

   A. 10 k, 15 k.
   B. 300, 200.
   C. 600, 300.
   D. 600, 800.

6. The term used to describe a DAC output that always increases for an increasing binary input count is:

   A. accurate.
   B. linear.
   C. monotonic.
   D. monolithic.

7. Which of the following is **NOT** a part of most DACs?

   A. counter.
   B. reference.
   C. resistor network.
   D. current switches.

8. The main function of an op amp in a DAC is:

   A. current-to-voltage converter.
   B. analog memory.
   C. voltage-to-current converter.
   D. power amplification.

9. The conversion speed of a DAC is essentially its:

   A. aperture time.
   B. clock rate.
   C. resolution.
   D. settling time.

10. A DAC that can produce the product of analog and digital inputs is called a(an):

    A. product detector.
    B. multiplying DAC.
    C. hybrid DAC.
    D. A-D converter.

11. The term used to describe the analog-to-digital conversion process is:

    A. analogize.
    B. linearize.
    C. digitize.
    D. binaryize.

12. The circuit with an analog input, reference input, and a binary output is called a/an:

    A. op amp.
    B. comparator.
    C. ADC.
    D. S/H.

13. A counter-ramp ADC has an 8-bit resolution, a 10 volt reference, and a clock speed of 100 kHz. With a 6 volt input, the conversion time is:

    A. 10 microseconds.
    B. 154 microseconds.
    C. 1.54 ms.
    D. 2.56 ms.

14. A 12-bit successive approximations ADC makes how many comparisons per conversion cycle?

    A. 1.
    B. 2.
    C. 12.
    D. 4096.

15. The second fastest form of ADC is:

    A. successive approximations.
    B. counter ramp.
    C. flash.
    D. V-F.

16. The fastest form of ADC is the:

    A. successive approximations.
    B. counter ramp.
    C. flash.
    D. dual slope.

17. The form of ADC most often used in digital multimeters is:

    A. successive approximations.
    B. counter ramp.
    C. flash.
    D. dual slope.

18. The primary circuit of a flash converter is a:

A. comparator.
B. DAC.
C. op amp.
D. R/2R network.

19. The primary advantage of a dual slope ADC is:

A. conversion speed.
B. accuracy.
C. low noise tolerance.
D. low cost.

20. The circuit that converts the output of a V-F ADC to binary or BCD is a:

A. counter.
B. shift register.
C. storage register.
D. DAC.

21. The error caused by the analog input changing during an ADC cycle is called:

A. monotonic error.
B. quantizing.
C. reference error.
D. aperture error.

22. An analog memory circuit used to eliminate aperture error is called a:

A. multiplexer.
B. track/store amplifier.
C. comparator.
D. op amp.

23. An 8-channel multiplexer is driven by a 20 kHz clock. The optimum sampling duration is:

    A. 6.25 microseconds.
    B. 5 microseconds.
    C. 100 microseconds.
    D. 400 microseconds.

24. An LSI IC that generates PCM is called a:

    A. successive approximations.
    B. modulator.
    C. CODEC.
    D. modem.

25. The process of sequentially converting multiple analog input signals to digital outputs is called:

    A. analog-to-digital conversion.
    B. serial ADC.
    C. pulse code modulation.
    D. time division multiplexing.

Unit 11 Examination

1. The most critical element in repairing digital equipment to prevent loss of productivity is:

   A. cost.
   B. proper test equipment.
   C. experienced repair personnel.
   D. fast service.

2. Which of the following components is most likely to fail first?

   A. switch.
   B. connector.
   C. fuse.
   D. diode.

3. Which of the following is most likely to cause a timing problem?

   A. propagation delay.
   B. power supply voltage.
   C. clock frequency.
   D. heat.

4. Which of the following is **NOT** an environment problem?

   A. power line spikes.
   B. heat.
   C. dirt.
   D. vibration.

5. Which of the following will give the false impression of being a hardware problem?

   A. mechanical failures.
   B. operator problems.
   C. excessive heat.
   D. software problems.

6. Which of the following is **NOT** an example of an internal IC failure?

   A. solder bridge.
   B. open weld.
   C. defective chip.
   D. shorted pins.

7. Short circuits can be caused by:

   A. broken pins.
   B. broken foils.
   C. defective IC socket.
   D. low currents.

8. A scratched PC board is most likely to cause a/an:

   A. short circuit.
   B. open circuit.
   C. logic high.
   D. logic low.

9. Chemicals often cause:

   A. shorts.
   B. open circuits.
   C. logic highs.
   D. logic lows.

10. Which of the following instruments is best for static testing?

    A. oscilloscope.
    B. multimeter.
    C. logic pulses.
    D. signature analyzer.

11. Which of the following is **NOT** a dynamic test instrument?

    A. logic monitor.
    B. oscilloscope.
    C. logic probe.
    D. logic analyzer.

12. A general purpose oscilloscope is best for measuring which of the following?

    A. logic levels.
    B. pulse transition time.
    C. frequency.
    D. distortion.

13. The test instrument that gives a visual output indication to a single logic input is called a:

    A. logic monitor.
    B. logic pulser.
    C. logic probe.
    D. logic clip.

14. Flashing output on a logic probe usually indicates which of the following inputs?

    A. open circuit.
    B. binary 0.
    C. binary 1.
    D. pulse train.

15. The most common instrument used to generate an input stimulus to a digital IC is called a:

    A. logic pulser.
    B. current tracer.
    C. logic probe.
    D. signature analyzer.

16. Defects such as shorts in wired ORs and bus systems are most easily found using a:

    A. logic probe.
    B. current tracer.
    C. logic pulser.
    D. multimeter.

17. The test instrument that collects and stores many simultaneous digital inputs is called a/an:

    A. oscilloscope.
    B. logic probe.
    C. logic analyzer.
    D. signature analyzer.

18. When the CRT display shows binary 0's and 1's, octal, or hex characters, which logic analyzer display mode is selected?

    A. timing.
    B. map.
    C. graphic.
    D. data.

19. Which logic analyzer mode is best for recognizing specific data words or bit patterns?

    A. timing.
    B. data.
    C. map.
    D. graphic.

20. The map mode in a logic analyzer generates which of the following outputs?

    A. 1's and 0's.
    B. timing waveforms.
    C. hex digits.
    D. signature pattern.

21. The dynamic test instrument with a single serial input and a 4-digit hex output display is called a:

    A. logic analyzer.
    B. signature analyzer.
    C. logic probe.
    D. logic monitor.

22. The main circuit in a signature analyzer is a:

    A. RAM.
    B. sampler.
    C. multiplexer.
    D. shift register.

23. The main causes of AC power not reaching the power supplies are:

    A. shorted circuit breaker.
    B. defective regulator.
    C. shorted power transformer.
    D. blown fuse.

24. The logic circuitry in a system is static. The problem is probably defective:

    A. power supply.
    B. clock.
    C. output display.
    D. connection.

25. Tracking a logic pulse from input to output is called:

    A. substitution.
    B. single stepping.
    C. signal tracing.
    D. current tracing.